

RESEARCH ARTICLE

# Awareness, treatment, and control of dyslipidemia in rural South Africa: The HAALSI (Health and Aging in Africa: A Longitudinal Study of an INDEPTH Community in South Africa) study

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## Abstract

Dyslipidemia is a primary driver for chronic cardiovascular conditions and there is no comprehensive literature about its management in South Africa. The objective of this study was to assess the prevalence, awareness, treatment, and control of dyslipidemia in rural South Africa and how they are impacted by different behaviors and non-modifiable factors. To fulfill this objective we recruited for this cohort study adults aged  $\geq 40$  years residing in the Agincourt sub-district of Mpumalanga Province. Data collection included socioeconomic and clinical data, anthropometric measures, blood pressure (BP), HIV-status, point-of-care glucose and lipid levels. Framingham CVD Risk Score was ascribed to patients based upon categories for 10 year cardiovascular risk of low ( $<3\%$ ), moderate ( $\geq 3\%$  and  $<15\%$ ), high ( $\geq 15\%$  and  $<30\%$ ), and very high ( $\geq 30\%$ ). LDL cholesterol control by risk category was defined according to South African Guidelines. Multivariable logistic regression models were built to identify factors that were significantly associated with dyslipidemia and awareness of dyslipidemia. From 5,059 respondents a total of 4247 subjects (83.9%) had their cholesterol levels measured and were included in our analysis. Overall, 67.3% (2860) of these met criteria for dyslipidemia, only 30 (1.05%) were aware of their condition, and only 21 subjects (0.73%) were on treatment. The majority have abnormalities in triglycerides (59.3%). As cardiovascular risk increased the rates of lipid control according to LDL level dropped. Multivariate logistic regression analyses showed that being overweight was predictive of dyslipidemia (OR 1.76; 95%CI 1.51–2.05,  $p < 0.001$ ) and dyslipidemia awareness (OR 2.58; 95%CI 1.19–5.58;  $p = 0.017$ ). In conclusion, the very low awareness and treatment of

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dyslipidemia in this cohort indicate a greater need for systematic screening and education within the population and demonstrate that there are multiple opportunities to allay this burden.

## Introduction

As the epidemiologic transition continues to unfold, chronic cardiovascular conditions grow in their impact upon morbidity, health-related costs, and mortality in low resource countries [1, 2]. Dyslipidemia, defined as abnormalities of serum cholesterol or triglyceride levels which portend heightened risk of cardiovascular events including myocardial infarction and stroke, is a primary driver for these changes [3]. According to multiple global estimates, elevated total cholesterol remains a significant risk factor for overall disability and premature death [4]. Fortunately, dyslipidemia prevalence and impact have been stagnant or slowly decreasing in prevalence and impact over the last twenty to thirty years globally—including in Sub-Saharan Africa [5].

However, country specific studies in South Africa tell a more concerning story. A 2012 South African survey revealed that 28% of women and 19% of men older than 18 had elevated total cholesterol, and 52% and 44% of men and women respectively had low levels of HDL [6]. Higher total cholesterol is less common in the Black African population, though dyslipidemia overall is grossly similar to global averages [6]. Community level assessments have found prevalence rates of dyslipidemia between 14% and 69% [7–9]. In South Africa, the treatment effects of HIV/AIDS complicate the picture of dyslipidemia [10]. This is particularly true given the well-known effect of protease inhibitors, a common component of antiretroviral therapy, which can elevate serum lipids by over 25% and accelerate progression towards cardiovascular events, but is also notable for first-line non-nucleoside and nucleoside reverse transcriptase inhibitors [11].

Unfortunately, there is nothing in the available literature about awareness, treatment, and control of dyslipidemia in South Africa. Though several reliable studies document prevalence rates of various lipid abnormalities, it is unknown how they are impacted by different behaviors and non-modifiable factors. These shortcomings in understanding what informs dyslipidemia prevalence, awareness, treatment, and control led to the development of the Cardiometabolic Disease in an Aging South African Cohort within the Health and Aging in Africa: Longitudinal Studies of an INDEPTH Community (HAALSI) Program. Specifically, this cohort study was initiated to discover the primary causes for changes in the prevalence, incidence, and risk factors of cardiometabolic disease in rural South Africa through the use of both self-reporting and direct assessment of disease and risks [12]. Baseline findings on the prevalence, awareness, treatment, and control of dyslipidemia in this cohort are reported. It is hoped that this will help elucidate the severity and impact of dyslipidemia in rural South Africa and provide guidance on potential avenues for control.

## Materials and methods

The HAALSI cohort is based in the Agincourt Health and Demographics Surveillance System (HDSS) site, a sub-district of rural Mpumalanga Province comprising approximately 116,000 people living in 21,000 households and 31 villages in an area of ~450km<sup>2</sup>. An annual census update, conducted by experienced local field staff, provides up-to-date denominator data on the full population with systematic recording of all vital events including deaths, births, and in-/out-migrations [13].

## Eligibility

All adults aged 40 years and older who had permanently resided in the Agincourt sub-district (Mpumalanga Province) for at least one year prior to the 2013 census update were eligible.

## Sampling and sample size

A total of 5,890 persons were identified for recruitment from the HDSS database using random sampling based on the 2013 Agincourt census data.

## Ethics approval

The study received ethical approvals from the Ethics Committees of three Institutions directly involved in the project: University of the Witwatersrand Human Research Ethics Committee (ref M141159), the Harvard T.H. Chan School of Public Health, Office of Human Research Administration (ref C13-1608-02) and the Mpumalanga Provincial Research and Ethics Committee (approved on 22nd October 2014).

## Recruitment and follow up

Prior to the survey, the HAALSI study was introduced to community members across the study villages, and discussed in-depth with a representative Community Advisory Group. This facilitated community review of study objectives and contributed to the effective response achieved.

Between November 2014 and November 2015 all identified individuals were visited at home by a supervised local field worker who described the study in the local language (Shang-aan), and requested permission to read and explain the relevant informed consent forms. Those who agreed to participate signed a consent form or, if not able to sign their name, were asked to have a literate witness sign and date the informed consent on their behalf. Field workers also signed and dated the informed consent form. The first follow-up telephone call (to sustain cohort participation) was made to all participants six months after the interview and future follow-up calls will be made at six-month intervals moving forward.

## Data collection

Two to three hour interviews were conducted in participants' households. The visit included a two part questionnaire: household and socioeconomic data then individual interview data; followed by physical and anthropometric assessments. Additionally, a random blood sample collection in the form of dried blood spots (DBS) was conducted. Blood sample collection was considered fasting if no caloric intake for at least 8 hours prior to the collection could be determined and that period was calculated as the reported difference between the time of the participant's last meal and the time of the interview. Data were entered on laptop computers using a Computer Assisted Personal Interview (CAPI) program. Data collected included BP (OmronM6W automated cuff; Omron, Kyoto, Japan), weight (GenesisGrowth Management Electronic Scale; Johannesburg, South Africa); height using a height sensor with infrared measurement; waist and hip circumferences with a flexible tape measure (SECA, Hamburg, Germany). Blood drops were collected via finger prick on Whatman 903 paper (Whatman, Buckinghamshire, UK) and used to measure HIV status (1–3 drops), high-sensitivity C-reactive protein (hsCRP), glucose in point of care machines (Caresense N Monitor, Seoul, Korea) and individual lipid levels (Cardiocheck PA Silver version; Indianapolis, Indiana, USA). Three blood pressure readings (systolic and diastolic) were obtained with 2 minutes between each reading and the mean blood pressure was calculated using the average between the second and

third reading[14]. All self-reported conditions were captured using the question “Have you ever been told by a doctor, nurse, or other healthcare worker that you have (condition)?”. Self-reported current medication use for dyslipidemia and HIV (anti-retroviral) was also obtained during the interview.

## Definitions

Dyslipidemia was defined by participants meeting one or more of the following criteria: total cholesterol  $>5.0$  mmol/L, LDL-cholesterol  $>3.0$  mmol/L, HDL-cholesterol  $<1.2$  mmol/L, triglycerides  $>1.7$  mmol/L, or self-reported treatment[6]. Framingham CVD Risk Score was ascribed to patients based upon categories for 10 year cardiovascular risk of low ( $<3\%$ ), moderate ( $\geq 3\%$  and  $<15\%$ ), high ( $\geq 15\%$  and  $<30\%$ ), and very high ( $\geq 30\%$ )[15]. LDL cholesterol control by risk category was defined according to South African Consensus Guidelines of LDL  $<3$  mmol/L for Framingham low/moderate risk, LDL  $<2.5$  mmol/L for high risk, and LDL  $<1.8$  mmol/L for very high risk[16].

Clinical determination of HIV status was determined by first using the Vironostika Uni-form 11 (Biomerieux, France) screening assay. Negative results were assigned a HIV-negative status, while positive results triggered a second (confirmatory) test using the Roche Elecsys (USA) assay to determine the viral load. If both screening and confirmatory tests were positive, a final status of HIV-positive was assigned and the viral load subsequently calculated. If the screening and confirmatory tests yielded opposing results, a third assay was run on the Siemens Centaur XP (USA) immunoassay. This third test served as the tie-breaker to determine a final HIV-positive or negative status, in accordance with World Health Organization (WHO) guidelines[17, 18]. HIV-positive status was defined as a self-reported history of being informed of the condition by a health professional or positive result on assay analysis.

Age stratification followed the WHO definition for elderly in developing countries ( $\geq 60$  years)[19] while Body Mass Index (BMI) in  $\text{kg}/\text{m}^2$  was used to categorize subjects as overweight ( $\text{BMI} \geq 25 \text{kg}/\text{m}^2$ ) using World Health Organization (WHO) cutoffs[20]. Socioeconomic status (SES) is a composite, constructed variable incorporating measures of traditional and modern wealth captured in the computerized questionnaire, using methodology created for Demographic and Health Surveys (DHS) and divided into 5 quintiles—higher SES included 4th and 5th higher quintiles[21, 22]. Immigrants were defined as the subjects who were born outside South Africa. Cardiovascular disease was defined by self-report of stroke, myocardial infarction, angina, or a diagnosis of angina by Rose criteria (World Health Organization Rose questionnaire is widely used in epidemiological studies and is a validated and standardised method for defining angina pectoris)[23]. Smoking status was defined by self-reported current smoking status. Awareness captured persons with a self-reported history of being informed of the condition by a health professional. The subset of persons reporting medication use among those aware of their condition was defined as those being treated. Finally, those deemed as having control of their condition was defined as the subset of persons who met target levels and who are also taking medication for the given condition, including dyslipidemia.

## Analyses

All analyses were conducted using STATA <sup>®</sup> V14 software. Continuous variables were compared using T test (expressed in mean values and standard deviations, since they were normally distributed) and categorical variables using Chi Square test (expressed in absolute numbers and percentiles). Multivariable logistic regression models were built to identify factors that were significantly associated with dyslipidemia and awareness of dyslipidemia. The variables included in the two models were the same (gender, HIV diagnosis, age, immigration

status, social economic status, cardiovascular disease and being overweight or obese) and were previously assessed in this population[24]. The results are presented using odds ratios and 95% confidence intervals. The level of significance was set at 5%.

## Results

From the full sample of 5,890 persons who were alive and residing in the area at the time of recruitment 5059 (85.9%) agreed to participate, 430 refused (7.3%), 353 (6.0%) were not located, and 48 (0.8%) were unable to participate. A total of 4247 subjects (83.9% from the participants) had their cholesterol levels measured and therefore were included in this analysis. The mean age of the population was 61.9±12.9 years with the dyslipidemic subjects being roughly the same age (61.8±12.6 years). The mean BMI was 27.4±6.96 kg/m<sup>2</sup> and was slightly higher in the dyslipidemic population (28.1±6.68 kg/m<sup>2</sup>) compared to non-dyslipidemic subjects (25.9±7.28 kg/m<sup>2</sup>). Additionally, the dyslipidemic subjects had a larger mean waist circumference and waist-to-hip ratio, had lower smoking rates and higher blood pressure and glucose levels than non-dyslipidemic patients. Regarding the effect of HIV positivity and treatment there was no statistical difference in dyslipidemia rates for subjects that were HIV positive, and HIV treatment was associated with lower rates of dyslipidemia. Clinical and laboratory characteristics of these participants are summarized in Table 1.

Overall, 67.3% (2860) of subjects met criteria for dyslipidemia, only 30 (1.05%) of those with dyslipidemia were aware of their condition, and only 21 subjects (0.73%) were on treatment. The majority of subjects with dyslipidemia had abnormalities in measured triglycerides

**Table 1. Overall, non-dyslipidemic and dyslipidemic population characteristics, Agincourt sub-district, South Africa 2015.**

Factor	Overall	Non-dyslipidemic	Dyslipidemic	p-value*
<i>n</i>	4247	1387	2860	
Male sex	1917 (45.1%)	666 (48.0%)	1251 (43.7%)	0.009
Age (years)	61.87 (±12.89)	61.95 (±13.36)	61.83 (±12.65)	0.770
Weight (kg)	72.08 (±17.68)	67.94 (±16.34)	74.10 (±17.95)	<0.001
Height (m)	1.63 (±0.09)	1.63 (±0.09)	1.63 (±0.09)	0.860
Body mass index (kg/m <sup>2</sup> )	27.36 (±6.96)	25.92 (±7.28)	28.06 (±6.68)	<0.001
Waist circumference (cm)	92.76 (±15.21)	88.77 (±14.10)	94.72 (±15.35)	<0.001
Waist/hip ratio	0.91 (±0.08)	0.89 (±0.08)	0.91 (±0.08)	<0.001
Systolic blood pressure (mmHg)	138.12 (±23.27)	136.17 (±22.80)	139.06 (±23.44)	<0.001
Diastolic blood pressure (mmHg)	82.13 (±12.62)	81.00 (±12.10)	82.68 (±12.83)	<0.001
Glucose (mmol/L)	6.68 (±3.20)	6.17 (±2.11)	6.93 (±3.59)	<0.001
Total cholesterol (mmol/L)	4.24 (±1.26)	3.63 (±0.80)	4.53 (±1.34)	<0.001
HDL-cholesterol (mmol/L)	1.57 (±0.55)	1.74 (±0.39)	1.49 (±0.59)	<0.001
Triglyceride (mmol/L)	1.76 (±1.57)	1.14 (±0.30)	2.06 (±1.83)	<0.001
LDL-cholesterol (mmol/L)	2.12 (±1.50)	1.67 (±0.62)	2.37 (±1.77)	<0.001
High-sensitivity CRP (mg/L)	3.28 (±3.02)	3.13 (±3.01)	3.35 (±3.03)	0.033
Smoker	379 (8.9%)	159 (11.5%)	220 (7.7%)	<0.001
HIV positive	1004 (23.7%)	338 (24.4%)	666 (23.3%)	0.440
HIV on treatment	490 (11.5%)	184 (13.3%)	306 (10.7%)	0.014
HIV without treatment	514 (12.1%)	154 (11.1%)	360 (12.6%)	0.160

Dyslipidemia defined as total cholesterol > 5 mmol/L **or** low-density lipoprotein (LDL) > 3.0 mmol/L **or** high-density lipoprotein (HDL) < 1.2 mmol/L **or** Triglycerides > 1.7 mmol/L **or** Self-reported treatment. Data given as mean ± SD or n (%)

\*p-value for comparison of dyslipidemic vs. non-dyslipidemic subjects

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**Table 2. Prevalence of dyslipidemia by different definitions in the HAALSI dyslipidemic population (n = 2860).**

Dyslipidemia category	n (%)
Total cholesterol > 5 mmol/L	1077 (37.66)
low-density lipoprotein (LDL) > 3.0 mmol/L	1050 (36.71)
high-density lipoprotein (HDL) < 1.2 mmol/L	1147 (40.10)
Triglycerides > 1.7 mmol/L	1696 (59.30)
Self-reported treatment	21 (0.73)

Dyslipidemia defined as total cholesterol > 5 mmol/L **or** low-density lipoprotein (LDL) > 3.0 mmol/L **or** high-density lipoprotein (HDL) < 1.2 mmol/L **or** Triglycerides > 1.7 mmol/L **or** Self-reported treatment

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(59.3%), with all other lipid irregularities ranging from 36.7 to 40.1% prevalence—summarized in Table 2. This translated to a population prevalence of elevated total cholesterol of 25.4%, elevated LDL of 24.7%, low HDL of 27.0%, and elevated triglycerides of 39.9%. The majority of reported treatments consisted of diet and weight loss (17/21), with only 4 subjects on allopathic medications. Herbal medicines were being taken by 9 of the 21 subjects under treatment. We assessed the relationship between HDL and triglycerides using a Pearson Coefficient and found that there was a statistically significant ( $p = 0.003$ ) and negative ( $r = -0.094$ ) relationship between HDL and triglycerides.

When dyslipidemic subjects were categorized by Framingham Cardiovascular risk it was found that half of subjects were low risk, with 11.3% meeting criteria for high or very high risk (Table 3).

Additionally, as calculated cardiovascular risk increased for dyslipidemic subjects the proportion of subjects with controlled LDL decreased (see Table 4).

According to the multivariate logistic regression analyses overweight or obesity was positively associated with both dyslipidemia and dyslipidemia awareness, while gender, higher SES bracket, HIV status, age  $\geq 60$  years old, being an immigrant and presence of co-morbid cardiovascular disease were not (Tables 5 and 6).

## Discussion

This analysis of the HAALSI cohort characterized a population which was middle-aged and older, overweight, and with a significant burden of dyslipidemia predominantly due to elevated triglycerides. Based upon the regression models, higher body weight was the only characteristic independently associated with of both dyslipidemia and dyslipidemia awareness.

**Table 3. Risk Category according to Framingham Risk Score among the HAALSI dyslipidemic population (n = 2,790).**

Risk Category	n	%
Low <sup>1</sup>	1,399	50.14
Moderate <sup>2</sup>	1,076	38.57
High <sup>3</sup>	235	8.42
Very High <sup>4</sup>	80	2.87

(1) Risk of cardiovascular events < 3% in 10 years.

(2) Risk of cardiovascular events  $\geq 3\%$  and < 15% in 10 years.

(3) Risk of cardiovascular events  $\geq 15\%$  and < 30% in 10 years.

(4) Risk of cardiovascular events  $\geq 30\%$  in 10 years.

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**Table 4. Subjects with LDL-cholesterol under control according to Risk Category among the HAALSI dyslipidemic population (n = 2,790).**

Risk Category	LDL-cholesterol controlled	
	n	%
Low (n = 1,399)	897	64.1
Moderate (n = 1,076)	682	63.4
High (n = 235)	123	52.3
Very High (n = 80)	9	11.3

LDL-cholesterol under control—Low risk and moderate risk—LDL cholesterol <3mmol/L; high risk—LDL cholesterol < 2.5mmol/L; very high risk—LDL cholesterol <1.8mmol/L.

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Awareness was also very rare in this population. HIV positivity and HIV treatment were not associated with higher rates of dyslipidemia. Specifically, 70.0% of HIV-positive subjects not on anti-retroviral therapy were dyslipidemic, while only 62.4% of those on therapy were ( $p = 0.01$ )—which was the opposite of the expected effect of anti-retroviral therapy. The absence of protease inhibitors in first line HIV treatment in Agincourt partially explains this[25]. Lipid lowering therapy was very low regardless of HIV treatment status so interaction with medical care also is not an explanation. A relatively small subset of the population was found to be at high or very high risk of future cardiovascular events according to the Framingham Cardiovascular Risk Score, and this sub-population had poor control of their lipids. Furthermore, only 4 of 1,214 of subjects with measured dyslipidemia in this baseline survey were receiving allopathic medications for control of cholesterol levels—indicating that there is an opportunity for a risk-based approach to statin therapy in this population.

Comparing the results of the HAALSI analysis to other studies from Sub-Saharan Africa there are differences in the underlying populations and lipid measurement which can explain some of the variation. Compared to the SANHANES survey, the HAALSI population had a similar burden of total cholesterol elevation, but had roughly half the prevalence of low HDL

**Table 5. Variables independently associated to dyslipidemia<sup>1</sup> in the HAALSI population.**

Variable	Dyslipidemia	
	OR (95% CI)	p
Gender (Female)	1.05 (0.92–1.20)	0.492
HIV negative <sup>2</sup>	0.98 (0.84–1.15)	0.853
Elderly <sup>3</sup>	1.04 (0.91–1.20)	0.497
Immigrant	0.96 (0.83–1.11)	0.567
SES <sup>4</sup> (higher)	1.13 (0.99–1.31)	0.066
CVD <sup>5</sup>	0.97 (0.80–1.17)	0.758
Overweight <sup>6</sup>	1.76 (1.51–2.05)	<0.001

(1) Total cholesterol > 5 mmol/L or low-density lipoprotein (LDL) > 3.0 mmol/L or high-density lipoprotein (HDL) < 1.2 mmol/L or Triglycerides > 1.7 mmol/L or Self-reported treatment.

(2) HIV negative—defined as negative self-report and negative on assay analysis.

(3) Age  $\geq 60$  years.

(4) Variable constructed incorporating measures of wealth, using methodology created for Demographic Health Surveys (DHS) divide in 5 quintiles—higher SES included 4<sup>th</sup> and 5<sup>th</sup> higher quintiles.

(5) Cardiovascular disease—self-report of Stroke/Myocardial Infarction/Angina or Angina by Rose criteria.

(6) Body mass index  $\geq 25$  kg/m<sup>2</sup>.

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**Table 6. Variables independently associated to dyslipidemia awareness<sup>1</sup> in the HAALSI population.**

Variable	Dyslipidemia	
	OR (95% CI)	p
Gender (Female)	1.55 (0.69–3.48)	0.286
HIV negative <sup>2</sup>	2.13 (0.63–7.21)	0.222
Elderly <sup>3</sup>	1.87 (0.84–4.15)	0.123
Immigrant	1.50 (0.68–3.32)	0.319
SES <sup>4</sup> (higher)	1.76 (0.83–3.73)	0.137
CVD <sup>5</sup>	1.31 (0.53–3.23)	0.562
Overweight <sup>6</sup>	2.58 (1.19–5.58)	0.017

(1) Ever told by a clinical practitioner that you have high cholesterol.

(2) HIV negative—defined as negative self-report and negative on assay analysis.

(3) Age  $\geq 60$  years.

(4) Variable constructed incorporating measures of wealth, using methodology created for Demographic and Health Surveys (DHS) divided into 5 quintiles—higher SES included 4<sup>th</sup> and 5<sup>th</sup> quintiles.

(5) Cardiovascular disease—self-report of Stroke/Myocardial Infarction/Angina or Angina based on Rose criteria.

(6) Body mass index  $\geq 25$  kg/m<sup>2</sup>.

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despite the population being older[6]. Total cholesterol elevation in the HAALSI cohort (25.4%) was very similar to a 2007 survey (25.6%) from the same Agincourt region by Thoro-good at al. which was a survey restricted to adults 35 years and older[8]. Manning et al (2016) identified a much higher prevalence rate of 69% for total cholesterol elevation (though a lower threshold of 4.5mmol/L) in Cape Town, but this was for obese subjects with ages 18 and older [9]. Finally, Maimela et al(2016) performed a survey of 20–59 year old subjects in the Dikgale area of Limpopo Province in Northeastern South Africa, which found a similar prevalence level for elevated total cholesterol of 25.6%[7]. Strikingly, the rates of different lipid abnormalities in the HAALSI cohort closely approximate the most recently published United States NHANES estimates (2012) with an overall dyslipidemia prevalence of 53%, elevated LDL of 27%, low HDL of 23%, and high triglycerides of 30%[26].

This analysis indicates two primary opportunities for improvement in cardiovascular disease prevention and lipid management. First, there is a defined and relatively small subset of the population at greater calculated cardiovascular risk who could definitively benefit from statin therapy—which is known to be both safe and cost-effective in low resource settings[27, 28]. Second, is a large awareness gap for dyslipidemia with profoundly low rates of not only pharmacotherapy but also diet and exercise therapy—indicating a need to improve screening and programming for first line non-pharmacologic therapy.

There are several limitations of this descriptive study. Primarily, the sub-district population from which the cohort was drawn has been part of a HDSS since 1992. This creates a specific situation of long-term population surveillance that might overrate the results of dyslipidemia awareness, as previously shown in a hypertension analysis from the same cohort[24]. However, the levels of dyslipidemia awareness were sufficiently low that this effect is unlikely to have produced any significant bias. Secondly, the blood samples were not collected from strictly fasting subjects, which is known to potentially inflate triglyceride levels inaccurately [29]. This potential effect was measured using a quality analysis from this data set, which identified that 76.0% of all subjects were, by self-report, not fasting a minimum of 8 hours at the time of blood sample collection. the proportion of fasting samples was significantly higher among non-dyslipidemic subjects (28.3%) when compared to dyslipidemic (22.4%) subjects

( $p < 0.001$ ). Similarly, the proportion of subjects fasting was also significantly lower for subjects with hypertriglyceridemia (17.8%) than those without (26%) ( $p < 0.001$ ). This difference was not seen for those categorized based on LDL cutoffs. Additionally, triglycerides and LDL (calculated based on total cholesterol and triglyceride levels) not a determinant in cardiovascular risk stratification given the use of Framingham Risk calculation per local guidelines and therefore our analysis—further minimizing the likelihood of meaningful miscategorization. The use of the CardioChek PA device for lipid measurement likely underestimates cardiovascular risk in our population. Per recent published validity assessments, the CardioChek PA seems to underestimate LDL, HDL, and total cholesterol, while being inaccurate but unbiased in its triglyceride measurements [30]. This contrasts with prior studies which validated the CardioChek PA against laboratory-based methods [31, 32]. Unfortunately, there is no venous draw validation for lipid values in the HAALSI data set.

There are multiple strengths to this study. The assessment of lipid awareness, treatment, and control is unique for studies performed in this region. Additionally, the formation of the HAALSI cohort will provide a suitable platform for the investigation of possible interventions for dyslipidemia and related cardiometabolic disorders and provide a greater understanding of the dynamic changes in behavior and population characteristics with respect to non-communicable diseases. The assessment of both HIV and migrant status as risk factors, allows for a more practical assessment of potential cardiometabolic disease risk factors which are characteristic of both the local region and sub-Saharan Africa in general. Finally, the assessment of all major lipoproteins is rare in large community studies and adds to the nuance of the information this paper provides on cardiovascular risk from lipid abnormalities.

## Conclusion

In conclusion, this baseline examination of the HAALSI cohort confirms the suspected notable contribution of dyslipidemia on overall cardiovascular risk in the Agincourt sub-district of rural South Africa, and demonstrates that there are multiple opportunities to allay this burden. Firstly, there is a subset of the population at high risk for cardiovascular events who could benefit from medical management with statin therapy, in the context of almost no current use. Secondly, our regression analysis and descriptive statistics demonstrates that overweight and obesity appear the primary modifiable risk factor to be targeted. Thirdly, the very low awareness of dyslipidemia in the population indicates a greater need for systematic screening and education within the population. It is hoped that ongoing HAALSI cohort investigations will further illuminate strategies and opportunities for dyslipidemia—and broader cardiometabolic disease—prevention and control in rural South and southern Africa.

## Supporting information

**S1 Survey. HAALSI survey original.**  
(DOCX)

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