Cascades of diabetes and hypertension care in Samoa: Identifying gaps in the diagnosis, treatment, and control continuum — a cross-sectional study

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Summary

Background Samoa is a Pacific Island country facing one of the highest burdens of non-communicable disease globally.

Methods In this study, we apply a cascade-of-care approach to understand gaps in the awareness, treatment, and control cascade of diabetes and hypertension in a cross-sectional, convenience sample of 703 young, high-risk Samoan adults (29.5-50.9 years).

Findings Non-communicable diseases were prevalent in the study sample: 19.5% (95% CI: 16.6%-22.7%) of participants had diabetes; 47.6% (95% CI: 43.7%-51.4%) presented with pre-diabetes or diabetes; 31.0% (95% CI: 27.5%-34.6%) had hypertension; and nearly 90% (95% CI: 86.7%-91.5%) had overweight or obesity. Among those with diabetes and hypertension, only 20.5% (95% CI: 13.9%-28.4%) and 11.8% (95% CI: 7.8%-16.9%) of participants were aware of their condition, respectively. Only 0.8% (95% CI: 0.0%-4.2%) of all participants with diabetes had achieved glycemic control; only 2.8% (95% CI: 1.1%-6.1%) of those with hypertension achieved control.

Interpretation We found a significant burden of diabetes and hypertension in Samoa, exceeding the recent prevalence estimates of other low- to middle-income countries by nearly two-fold. A severe unmet need in both detection and subsequent control and monitoring of these chronic conditions exists. Our results suggest that the initial diagnosis and surveillance stage in the cascade of care for chronic conditions should be a major focus of primary care efforts; national screening campaigns and programs that leverage village and district nurses to deliver community-based primary care may significantly impact gap closure in the NCD cascade.

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Research in Context

Evidence before this study

Care cascade approaches have been predominantly and historically utilized to assess HIV care. However, recent works have expanded this approach to noncommunicable diseases (NCDs) as a means of measuring the effectiveness of, and identifying the gaps in, health care delivery for chronic diseases. We searched PubMed and Google Scholar using the following search terms "care cascade", "NCD/diabetes/hypertension care cascade" in English up to March 19, 2020. We identified several papers reporting NCD care cascade approaches including 1) care cascade analyses of diabetes and hypertension and the calculation of unmet need for care in Sub-Saharan and South Africa, 2) a comprehensive examination of hypertension care in 44 low- and middle-income countries, and 3) two assessments of the hypertension care cascade in Samoa and American Samoa. Of those latter two studies, one was limited by using dated samples (that were presumed to be no longer applicable in the context of a rapidly changing environment) and the other by small sample size.

Added value of this study

Our study is the first analysis of both hypertension and diabetes care cascades in a younger cohort of adult Samoans. As many adults in Samoa are impacted by a dual disease burden of hypertension and diabetes, this study presents a more comprehensive examination, compared to previous studies, of the multiple gaps and losses within NCD care cascades likely affecting the population. Additionally, we build upon existing analyses by presenting the first assessment of unmet need, a quantitative measure estimating the magnitude of healthcare delivery weaknesses, for hypertension and diabetes care in Samoa. We found that losses within both the hypertension and diabetes care cascades were higher than those observed in several other low and lower middle lower income countries, and that the majority of those experiencing NCDs faced an unmet care need. Our results also provide insights about where in the care cascade attention and resources are needed most, namely the diagnosis and surveillance stages.

Implications of all the available evidence

Our findings, along with those of earlier studies, reiterate that gaps exist in NCD care continuums, regardless of country income status and in the face of a growing NCD epidemic. As more people around the world face the risk of NCDs and their associated comorbidities, it is imperative for health systems to expand accessibility and facilitate engagement and retention in care. Current efforts in Samoa to reinvigorate village-based care, including the broad implementation of the recently introduced PEN *Fa'a Samoa* program and upcoming changes in Samoan health policy to refocus on primary care, may benefit from our identification that the screening and diagnosis stages are where most individuals are lost in care. A targeted improvement of health programs focused on NCD screening would be useful in this setting. Additionally, the repetition of NCD cascade of care analyses in coming years may serve as a useful evaluation tool throughout the Pacific.

Introduction

Low- and middle-income countries bear the greatest health and economic burden of the non-communicable disease (NCD) pandemic.[1] Pacific Islanders are disproportionately affected compared to other global regions,[2–5] leading to the 2011 Pacific Islands Forum declaration that the "Pacific region is in an NCD crisis."[6–8]

Samoa — an upper-middle income country at the time of the study[9]—faces some of the highest rates of diabetes and obesity globally after an epidemiologic transition characterized by urbanization, introduction of a high fat, nutrient-poor diet, and reduced opportunities for work/subsistence farming-related physical activity.[2,6,10,11] Between 1978 and 2013, Type 2 diabetes prevalence among adults (25-64 years) increased from 1.2% to 19.6% in men and 2.2% to 19.5% in women.[12] In a similar analysis conducted between 1991 and 2013, the hypertension prevalence in Samoa increased from 18.3 to 33.9% in men and 14.3 to 26.4% in women, with one-third of this increase attributed to rising obesity levels.[13] Interestingly, increases in cardiometabolic risk factors such as obesity were highest in the youngest age group of individuals 24-34 years (4.6% per five years).[12]

Supporting evidence-based practices for surveillance, control, and management of NCDs is a priority in the Pacific Islands.[14] One approach to monitoring effectiveness of long-term NCD management is to examine cascades of care: the continuum of prevalence; awareness of risk, diagnosis, referral, treatment, and subsequent control or eradication of disease.[15,16] Originally used to evaluate HIV care, this approach has been expanded to NCDs in an effort to shift health care delivery from predominantly episodic acute care towards long-term, comprehensive programs for chronic conditions.[17–20] Knowledge about where in the care continuum people at risk for NCDs and diagnosed patients are lost to care can inform the targeting of intervention programs and delivery of health services and may be a useful metric of health system performance.[21]

Continuity of NCD care is challenging; a cross-sectional study of pooled, individual-level population-based data from 44 Low- and middle-income countries (LMICs), for example, revealed that among the 17.5% of those with hypertension (Blood Pressure (BP) ≥140/90 mmHg or reported use of medication) only 39% had been diagnosed. Thirty percent of those diagnosed were on a treatment regimen, and only 10% of those with hypertension had achieved control over their condition.[21] Likewise, data from nationally-representative surveys conducted between 2008 and 2016 in 28 LMICs indicated that among the 8.8% of those with diabetes, only 64.3% had ever been tested with a blood glucose measurement, 44% were aware of their diagnosis, 38.4% received treatment, and only 22.8% had achieved control of their disease.[18]

There have been few cascade of care studies completed in the Pacific Island nations, but to our knowledge all of the studies to date have taken place in either Samoa or American Samoa. Keighley et al. used data on hypertension and diabetes and freported that in 2002 in American Samoa, more than 85% of men and 80% of women under the age of 45 who were found to have hypertension during a health research study were unaware of their condition.[22] Similarly, in 2003 in Samoa, 96% of men and more than 80% of women of the same age were unaware that they had hypertension.[22] The same authors described a better, but still problematic, scenario for diabetes in American Samoa, with 40% of men and women under 45 years unaware of their condition.[22] More recently (2018), Fraser-Hurt et al. purposively surveyed four Samoan villages, selected based on their participation in a national NCD intervention (two villages participated, two did not), and identified deficits in hypertension and diabetes screening, diagnosis, and control despite there being available care and medication at community facilities and the national hospital, often subsidized by government funding.[23] The existing studies are somewhat limited, however, by the age of the data, their targeted sampling approach, and the fact that little attention has been paid to understanding whether social or demographic characteristics are associated with the likelihood of being retained in the continuum of care for chronic conditions.

To address these knowledge gaps, we report the prevalence of diabetes and hypertension in a cross-sectional, convenience sample of young Samoan adults (29.5-50.9 years), who are at particular risk of early NCD onset given the high prevalence of obesity among this age group.[12] We then employ a cascade-of-care approach to characterize and identify unmet need in the continuum of care for both hypertension and diabetes and examine demographic correlates of disease awareness.

Methods

Study Design and Sample Size

This cross-sectional study took place in Samoa between June and August 2018. In 2018, Samoa's population was estimated to be 199,243[24] resident on the two main islands, ''Upolu, where the urban center and tertiary care facility is located, and Savai'i. The four census regions − the Apia Urban Area (AUA; urban), North-West 'Upolu (NWU; peri-urban), Rest of 'Upolu (ROU; rural) and Savaii (SAV; rural) serve as a proxy for urbanization and also reflect exposure to nutrition transition, with more rural areas still engaged in some degree of subsistence-related agriculture and urban residents consuming more energy-dense, nutrient-poor, imported foods.[25,26]

The current study is a secondary analysis of data collected as part of a larger study. Our convenience sample of 703 Samoan adults was recruited during village-based screening to identify participants for a longitudinal study of genetic influences on energy balance. This screening took place with the goal of identifying ∼40 individuals with two copies of a missense variant at rs373863828 in Creb 3 Regulatory Factor (*CREBRF*); a variant that is known to be associated with body mass index (BMI)[27] and hypothesized to influence energy balance. Given the proportion of the population expected to be homozygous for the variant (6-10%), our recruitment goal was 700 individuals. Screening occurred in 12 villages on 'Upolu island and did not include residents of Savai'i due to transport and logistical considerations associated with the intensive protocols of the larger study, which was based in our laboratory in Apia. Large villages (population ≥500), within 25 minutes of Apia, were targeted for ease of recruitment, data collection and follow-up in the later longitudinal study. Village representatives announced the availability of this screening program, which offered BP and glycated hemoglobin measurements (because diabetes was an exclusion criterion for the larger study), anthropometry, and several interview modules.

Participants were considered eligible for this analysis if they were of Samoan ethnicity (measured by self-report of four Samoan grandparents) and between 29.5 and 50.9 years of age; this age range was the focus of the larger energy balance study anticipating the likelihood of observing weight gain in a longitudinal study, versus older participants whose weight is likely more stable. Restricting eligibility to those of Samoan ethnicity only was also a requirement of the parent study, since the gene variant of interest in that study is common among those of Samoan ancestry.[27] Exclusion criteria included participation in our group's prior genetic studies, other family members' prior participation (to minimize sample relatedness), being pregnant, current use of weight loss medication, history of weight loss surgery, and adopting a major diet/physical activity program or loss of >5% of body weight in the past year.

Samoan research assistants provided information about the study and data collection protocols, informed participants about their rights as study participants, and gained informed consent. Procedures were approved both by the Yale University Institutional Review Board (HIC Protocol: #2000021910) and the Health Research Committee of the Samoan Ministry of Health.

Measures

To calculate BMI, height was measured to the nearest 0.1 cm using a portable SECA anthropometer (SECA 213, Seca GmbH & Co., Hamburg, Germany) and weight to the nearest 0.1 kg using a Tanita HD 351 digital scale (Tanita Corporation of America, IL). After a 10-minute seated rest period BP was measured three times, with 3-minute rest periods between measurements,

using an Omron HEM907 XL digital monitor (Omron Healthcare, IL). The second and third measurements were averaged for analysis (removing the first to reduce risk of "white coat syndrome" elevations during initial measurement). HbA1c was measured with a random finger-prick blood sample (A1C Now, PTS Diagnostics, IN). Fasting Blood Glucose (FBG) (Bayer Contour, NJ) was measured in a small number of participants, where HbA1c kits were unavailable (based on supply shortages). Participant demographic characteristics (age, sex, and educational attainment) were self-reported.

Risk Factor Definitions & the Care Cascade

Polynesian BMI cutoffs were used to classify participants as having healthy weight, overweight, or obesity based on ranges of <26 kg/m², 26−32 kg/m², and >32 kg/m², respectively, based upon body composition studies showing that Polynesians have more lean tissue per kilogram of weight than European, Asian or African ancestry groups.[28,29] Hypertension was defined according to local standards for screening and referral as having either a mean systolic BP≥140 mmHg, diastolic BP≥90 mmHg, or current use of hypertension medication.[30] Type 2 diabetes was considered to be present if HbA1c was ≥6.5%, FBG was ≥126 mg/dl, or participants were currently taking medication (pills or insulin) for diabetes; pre-diabetes was defined as 5.7≤HbA1c≤6.4% or 110≤FBG≤125 mg/dL.[31] Participants were provided with immediate feedback on their weight status, BP, and diabetes risk. Written referrals to the local health care system were provided to any individuals whose BP or HbA1c/FBG exceeded the values noted above.

While presence of diabetes or hypertension, assessed using the measures described above, formed the first stage of the care cascade, awareness of diabetes and/or hypertension (the second stage of the cascade) was based on self-report of a prior diagnosis by a physician. This information was obtained as part of a questionnaire focused on health history, diagnoses of cardiometabolic NCDs, and medication use for any reported diagnoses (the third cascade stage). Among individuals who reported a diagnosis and current medication use, those with an HbA1c<6.5% or FBG<126 mg/dl were categorized as having controlled diabetes, and those with a systolic BP <140 mmHg or a diastolic BP <90 mmHg were categorized as having controlled hypertension according to AHA guidelines at the time of the study.[32] Control of a condition was the fourth cascade stage.

Data Analysis

Participants were excluded from analyses (n=14) if they were missing key socio-demographic (n=5) or BP/HbA1c/FBG data (n=9) yielding a final sample of N=689 (Figure 1).

The distribution of hypertension and diabetes by sex, age, census region, BMI category, and education level were evaluated using either analysis of variance (ANOVA; continuous variables) or chi-square statistics (χ^2; categorical variables). NCD prevalence and risk factors were described by 10-year age group. Care cascades were constructed for diabetes and hypertension with four progressive stages: [1] total diabetes or hypertension prevalence among the study population; [2] among those classified as having hypertension or type 2 diabetes, awareness of their condition based on prior diagnosis; [3] among those aware of their condition, the proportion currently using medication for that condition; and [4] among those on medication, the proportion currently in control. Then, these four categories were used to determine the percentage of individuals with either diabetes or hypertension lost across the care cascade according to the methods outlined by Stokes et al.[33] The proportion of participants who reached each stage was calculated by using the number of participants from the subsequent stage as the numerator and the total prevalence as the denominator in each case. Participants "lost" were calculated by subtracting the proportion of participants who reached each subsequent stage. Unmet need was calculated by subtracting the proportion of participants with controlled diabetes or hypertension from the total prevalence of the respective condition.

Among participants with hypertension or type 2 diabetes, sociodemographic correlates of diabetes and hypertension awareness were examined using bivariate and multivariable logistic regression analyses. Bivariate comparisons were presented as unadjusted odds ratios (ORs) and multivariable comparisons were presented as adjusted ORs. Covariates were selected using a backwards elimination model to reduce multicollinearity and retained in the final multivariable logistic regression model if they were associated with either awareness of diabetes or hypertension diagnoses, respectively, at the p<0.05 level. Statistical analyses were performed using SAS software, version 9.4 (SAS Institute Inc., NC). P-values (two-sided) <0.05 were considered statistically significant. Error represents 95% confidence intervals.

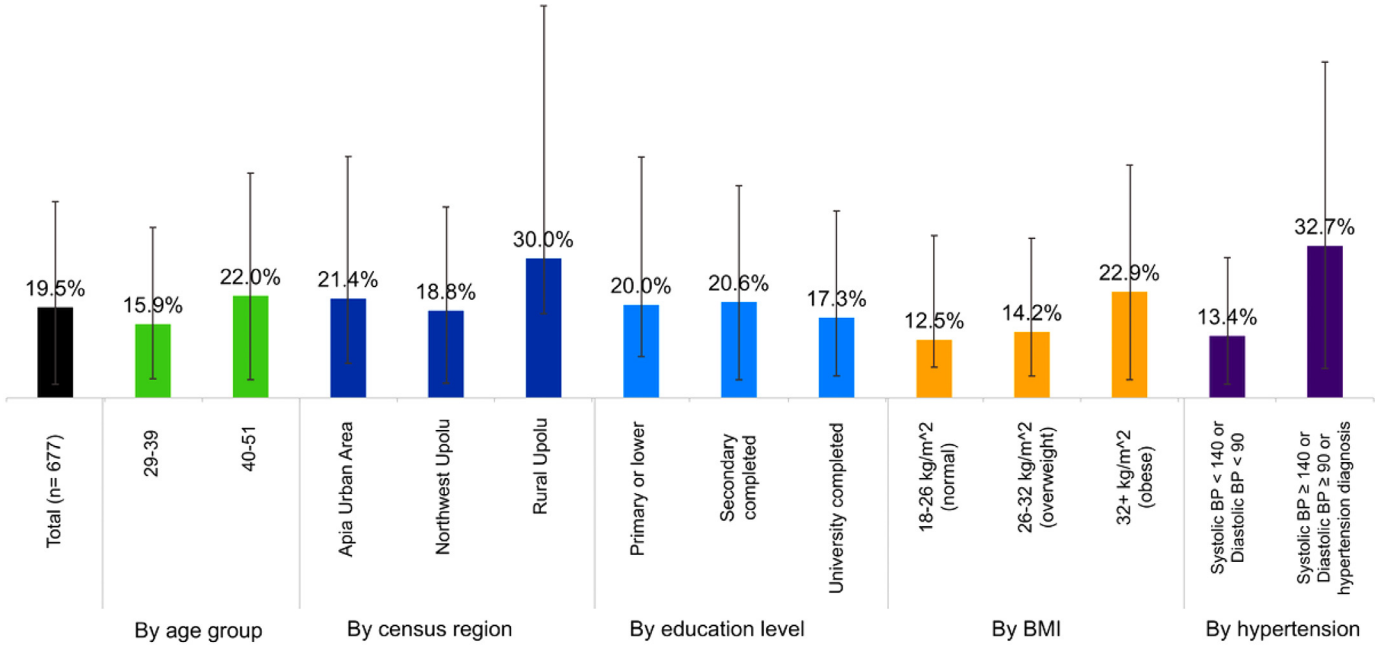### Role of the Funding Sources

Results

Sociodemographic and clinical characteristics

The mean age of participants was 41.0 ± 5.7 years and 52.0% (n=358) were female (Table 1). More than half of participants had completed secondary education

*Error bars represent 95% confidence intervals.

Figure 1. Prevalence of diabetes by study variables.
*Error bars represent 95% confidence intervals.

Articles

Characteristic	n (%) Total Sample (n= 689)	n (%) Male (n= 331)	n (%) Female (n= 358)	p[§]
Age (years), mean ± SD	41.0 ± 5.7	40.7 ± 5.8	41.2 ± 5.6	0.30
Age category (years)				0.11
29.5 - 39	276 (40.1%)	143 (43.2%)	133 (37.3%)	
40 - 51	412 (59.9%)	188 (56.8%)	224 (62.8%)	
Census region				0.00
Apia Urban Area (AUA)	103 (15.0%)	66 (19.9%)	37 (10.3%)	
Northwest 'Upolu (NWU)	566 (82.2%)	256 (77.3%)	310 (86.6%)	
Rest of 'Upolu (ROU)	20 (2.9%)	9 (2.7%)	11 (3.1%)	
Education level				<0.0001
Primary or lower	65 (9.5%)	30 (9.1%)	35 (9.8%)	
Secondary completed	395 (57.7%)	163 (49.5%)	232 (65.2%)	
University completed	225 (32.9%)	136 (41.3%)	89 (25.0%)	
BMI category (kg/m^2)				0.00
< 26 (healthy weight)	74 (10.8%)	39 (11.8%)	35 (9.8%)	
26 − 32 (overweight)	185 (26.9%)	109 (32.9%)	76 (21.4%)	
> 32 (obesity)	428 (62.3%)	183 (55.3%)	245 (68.8%)	
HbA1c (%), mean (n) (min, max) ± SD	6.1 (n=646) (4.0, 13.0) ± 1.7	5.9 (n=301) (4.0, 13.0) ± 1.5	6.2 (n=345) (4.0,13.0) ± 1.8	0.08
FBG (mg/dl), mean (n) (min, max) ± SD[¶]	124.0 (n=31) (82, 417) ± 64.1	124.7 (n=24) (82, 417) ± 72.1	121.9 (n=7) (97, 170) ± 24.4	0.92
Diabetes status†				0.30
No diabetes	355 (52.4%)	172 (52.9%)	183 (52.0%)	
Pre-diabetes	190 (28.1%)	97 (29.9%)	93 (26.4%)	
Diabetes	132 (19.5%)	56 (17.2%)	76 (21.6%)	
Blood pressure (mmHg)				
Systolic BP, mean ± SD	126.3 ± 17.4	131.3 ± 16.3	121.6 ± 17.1	<0.0001
Diastolic BP, mean ± SD	82.0 ± 12.6	83.3 ± 12.7	80.9 ± 12.4	0.01
Hypertension‡				0.01
No	472 (69.0%)	212 (64.2%)	260 (73.5%)	
Yes	212 (31.0%)	118 (35.8%)	94 (26.6%)	

Table 1: **Sociodemographic and clinical description of the study population***

* Numbers may not sum to totals due to missing data, and column percentages may not sum to 100% due to rounding.

¶ FBG (Fasting Blood Glucose) presented only for those missing HbA1c values.

† Diabetes= HbA1c ≥ 6.5% or FBG ≥ 126 mg/dl, or current use of medication. Pre-diabetes= 5.7% ≤ HbA1c ≤ 6.4% or 110 mg/dl ≤ FBG ≤ 125 mg/dl.

‡ Hypertension = systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg, or current use of medication.

§ p-value for differences by sex represents one-way ANOVA F-test for continuous variables and χ^2 test for categorical variables.

(n=395, 57.7%); a larger proportion of males than females had a university degree (p<0.0001)

Approximately 90% (95% CI: 86.7%-91.5%) of participants had overweight or obesity, but there were significant sex differences in overweight and obesity prevalence (p=0.001; Table 1) with more females having obesity and more men overweight. Nearly half, 47.6% (95% CI: 43.7%-51.4%), of participants presented with either pre-diabetes or diabetes; 19.5% (95% CI: 16.6%-22.7%) had diabetes. Males and females differed significantly with regards to systolic and diastolic BP (p<0.0001 and p=0.013, respectively). Females were less likely than males to have hypertension (26.6% versus 35.8%, p=0.01).
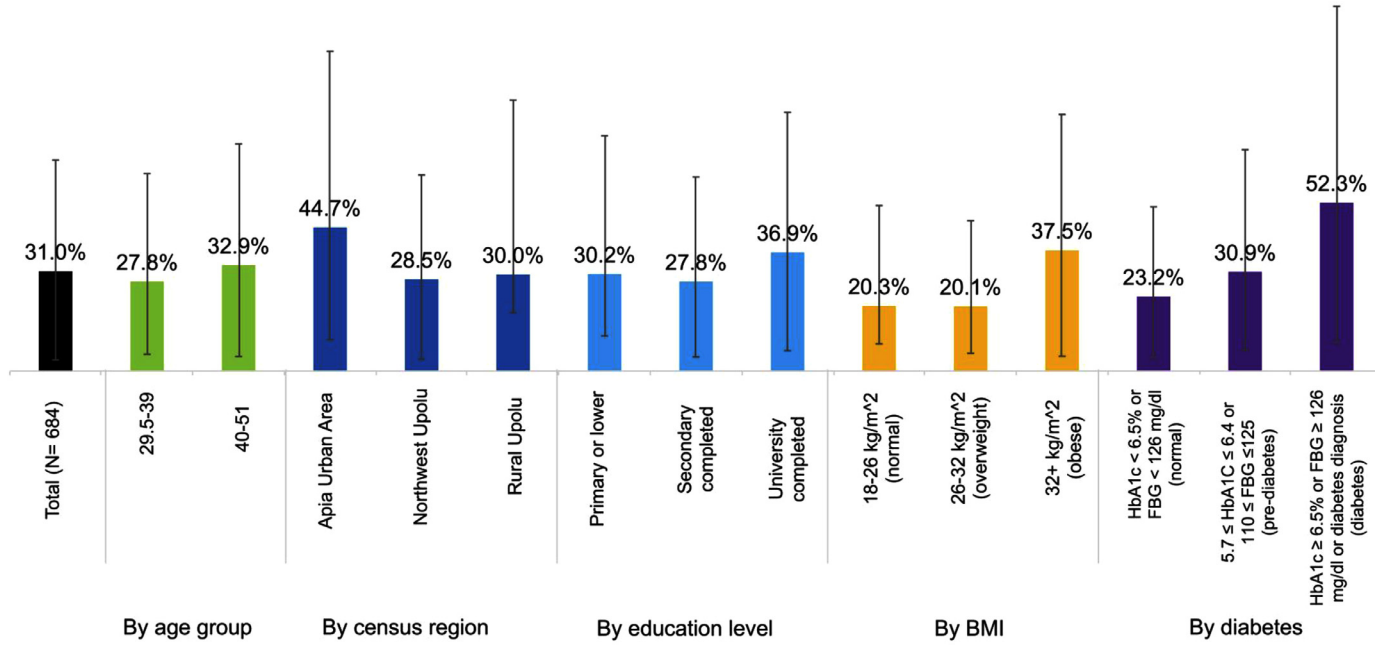
Prevalence of diabetes and hypertension by sociodemographic characteristics

A higher percentage of those aged 40-51 years had diabetes compared to those aged 29-39 (Figure 1) (22.0%

versus 15.9%), and diabetes decreased with increasing education. Prevalence was higher in the ROU region, although this finding should be interpreted with caution given the small number of participants from this region. Participants with obesity had a higher prevalence of diabetes compared to those with a BMI in the normal or overweight range, and those with hypertension had a prevalence of diabetes of nearly 33%. Sex-stratified analyses describing associations among diabetes and sociodemographic and health characteristics are presented in Supplementary Figure 1.

Similar to the prevalence of diabetes, the prevalence of hypertension was highest for those who were age 40-51 (32.9%) compared to those who were 29-39 (27.8%; Figure 2). There was a striking trend in hypertension prevalence by census region and education; those residing in the AUA and with a university degree had higher prevalence compared to those with either a primary or secondary education. Over one-third of those who were

Figure 2. Prevalence of hypertension by study variables.
*Error bars represent 95% confidence intervals

obese and over half of those with diabetes had hypertension. Supplementary Figure 2 shows sex-stratified associations of hypertension and sociodemographic and health characteristics.

Cascades of care: Awareness of diagnosis, treatment, and control of diabetes and hypertension

Among those with diabetes, only 20.5% (95% CI: 13.9%-28.4%) had received a prior diagnosis and were aware of their condition; 77.8% (95% CI: 57.7%-91.4%) of those with a prior diagnosis were on medication, and of those on medication, only 4.8% (95% CI: 0.1%-23.8%) had HbA1c/FBG values indicative of glycemic control (Figure 3). Of all participants with diabetes, only 0.8% (95% CI: 0.0%-4.2%) demonstrated glycemic control, yielding an unmet need for diabetes care of 99.2%.

Among participants with hypertension, only 11.8% (95% CI: 7.8%-16.8%) had a prior diagnosis; 80% (95% CI: 59.3%-93.2%) of those previously diagnosed were using medications, and of those on medication, only 30% (95% CI: 11.9%-54.4%) of participants had BP measurements indicative of BP control (Figure 4). Only 2.8% (95% CI: 1.1%-6.1%) of all study participants presenting with hypertension had achieved clinical control, yielding an unmet need for hypertension care of 97.2%.

Factors influencing awareness of diagnosis

Although females had twice the odds of being aware of their diabetes compared to males, this association did not reach statistical significance. There were no other significant or noteworthy associations with reporting a prior diabetes diagnosis (Table 2). Similarly, females were significantly more likely to be aware of their hypertension (Table 3), but no other correlates were identified.

Discussion

NCDs are now responsible for more than eight out of ten deaths in the Pacific region,[34] creating unsustainable strain on health care systems. Here we report low levels of awareness, treatment, and subsequent control of diabetes and hypertension among a relatively young cohort of Samoan adults 29 to 50 years of age. While widespread medication use among those aware of their condition indicates engagement with the healthcare system, very poor levels of control persisted among those with a treatment regimen.

We found a significant burden of diabetes and hypertension in Samoa, exceeding the recent prevalence estimates of other low- to middle-income countries by nearly two-fold.[18,21] Although our findings cannot be generalized nationally, diabetes and hypertension prevalence estimates are comparable to the most recent national age- and sex-specific estimates for these conditions (2013, participants aged 25-64 years),[12,13] despite

the younger overall age of our sample in comparison to the 2013 survey, suggesting an increasing burden of disease. The distribution of both conditions by age and BMI were as expected, with increasing prevalence with age and obesity risk. Overall, we identified substantial gaps in care at all stages of the care cascade, most notably at the stage of awareness of either a diabetes or hypertension diagnosis. We believe that this finding reflects a lack of an initial connection to the healthcare system to facilitate timely screening. While many factors may prevent detection of these NCDs, a perception among Samoan adults that these conditions do not affect a relatively young, healthy population may be contributing, in part, to delayed diagnosis at a stage of severe disease or complications resulting in a hospital admission.

Given the prevalence of diabetes and hypertension, the almost universal unmet need for care is worrisome and should be a priority for health policy makers. Lack of awareness among participants who recorded elevated HbA1c/FBG or BP was responsible for the greatest losses in the care cascade, indicating systematic deficits in screening and surveillance. In fact, loss at this step was similar to that observed in 2003,[22] suggesting that the move away from de-centralized, village-based primary care that began in the early 1990s and continued until major reform shortly after this data collection was completed, was ineffective at better identifying chronic disease. Given the relative proximity of our study villages to the major tertiary care center in Apia, we speculate that even greater lack of awareness may exist in more rural areas of the country.

The proportion of participants with HbA1c/FBG values in the diabetes range but who had not received a prior diagnosis was far greater than estimates of 27.8% for the U.S., 41% for rural Malawi, 47.5% for India, and 53.7% for South Africa.[20,33,35,36] Our relatively young cohort may explain the lack of awareness since NCDs are often considered diseases of old age in Samoa and younger individuals tend to underestimate risk.[37] Similarly, reported awareness of hypertension in Samoa was lower than in many LMICs.[21] While total unmet need was similar for both conditions, our findings suggest that diabetes is more effectively identified than hypertension, mirroring findings from Samoa in 2003.[22] The proportion of participants aware of their hypertension (12%) was much lower than that of diabetes (20%), a trend similar to that observed in Peru (48.3% versus 71.1%).[38] This is likely due to the asymptomatic nature of hypertension, which is rarely detected during its early stages.[39]

Females were more likely than males to report awareness of their hypertension; although the trend was the same, the statistical association did not extend to diabetes. This might be attributed in part to more frequent BP measurement compared to diabetes screening in maternal health services, as well as general health-
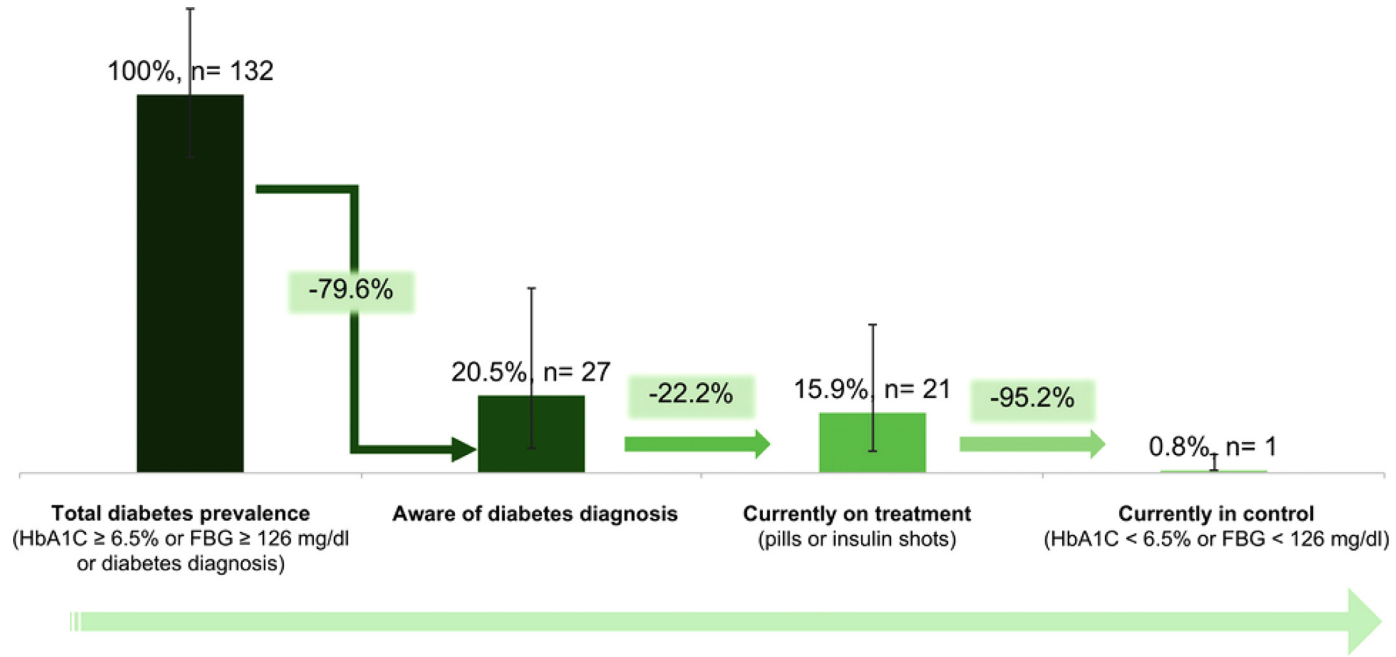
Figure 3. Diabetes treatment cascade.

*Percentage values represent the proportion of participants lost during that particular stage in the continuum of care as a fraction of the preceding stage. For example, 21 of 27 participants who were aware of their diabetes diagnosis (77.8%) were currently on treatment, representing a 22.2% loss during this stage. Error bars represent 95% confidence intervals.
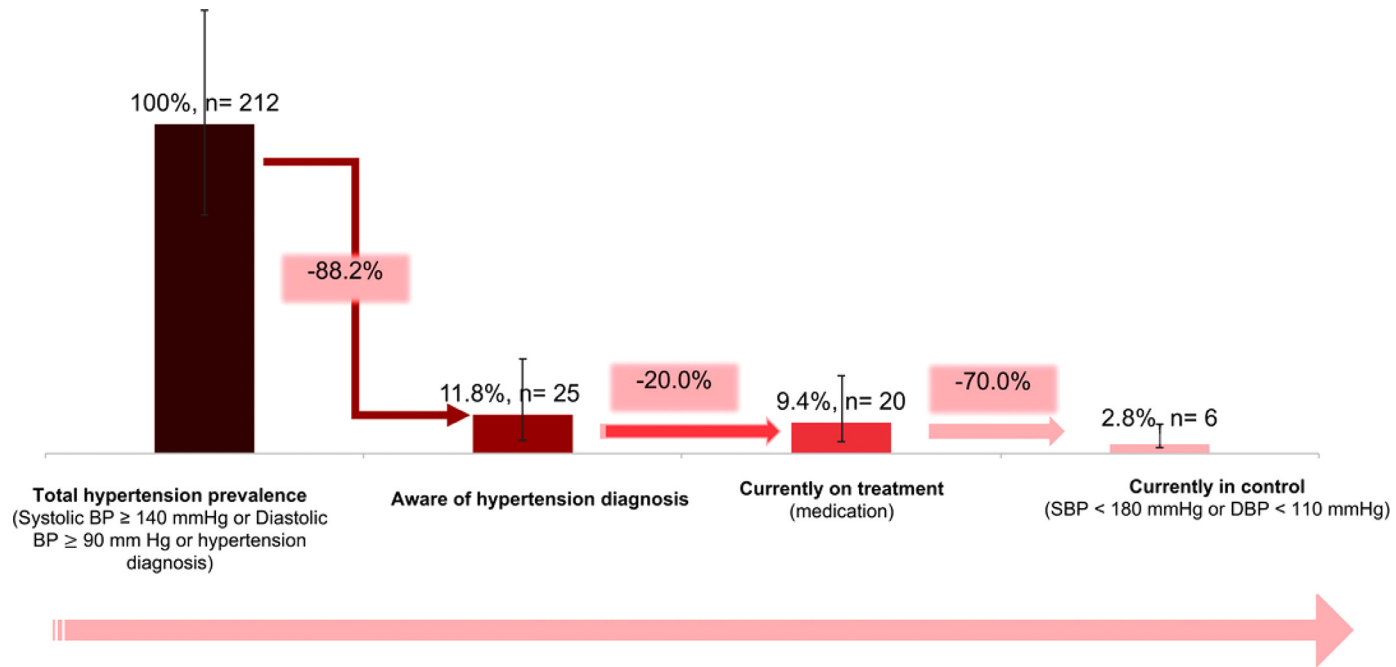
Figure 4. Hypertension treatment cascade.
*Percentage values represent the proportion of participants lost during that particular stage in the continuum of care as a fraction of the preceding stage. For example, 6 of 20 participants who were both aware of their hypertension diagnosis and currently on a treatment regimen (30.0%) were in control, representing a 70.0% loss during this stage. Error bars represent 95% confidence intervals.

Characteristic	N*	Aware of diabetes diagnosis† N(%)	Unadjusted OR (95% CI)	p	Adjusted OR¶ (95% CI)	p
Sex						
Male	56	8 (14.3%)	1.0		1.0	
Female	76	19 (25.0%)	2.0 (0.8 − 5.0)	0.13	2.1 (0.8 − 5.5)	0.15
Age category (years)						
29.5- 39	43	7 (16.3%)	1.0		1.0	
40- 51	89	20 (22.5%)	1.5 (0.6 − 3.9)	0.41	1.1 (0.4 − 3.1)	0.79
Census region						
AUA	22	5 (22.7%)	1.0		1.0	
NWU	104	22 (21.2%)	0.9 (0.3 − 2.8)	0.87	0.6 (0.2 − 2.0)	0.41
ROU	6	0 (0.0%)	-	-	-	-
Education level						
Primary or lower	13	4 (30.8%)	1.0		1.0	
Secondary completed	80	17 (21.3%)	0.6 (0.2 − 2.2)	0.45	0.7 (0.2 − 3.0)	0.64
University completed	38	6 (15.8%)	0.4 (0.1 − 1.8)	0.25	0.5 (0.1 − 2.6)	0.44
BMI category (kg/m^2)						
< 26 (healthy weight)	9	3 (33.3%)	1.0		1.0	
26- 32 (overweight)	26	6 (23.1%)	0.6 (0.1 − 3.2)	0.54	0.8 (0.1 − 5.0)	0.85
> 32 (obesity)	96	17 (17.7%)	0.4 (0.1 − 1.9)	0.26	0.6 (0.1 − 2.8)	0.46

Table 2: Bivariate and multivariable associations between study variables and awareness of diabetes diagnosis
* Numbers may not sum to total (n= 132) due to missing data.
† Awareness was based on participant report of a prior diabetes diagnosis.
¶ OR adjusted for all other variables presented (sex, age category, census region, education level, and BMI category).

Characteristic	N*	Aware of hypertension diagnosis† N(%)	Unadjusted OR (95% CI)	p	Adjusted OR¶ (95% CI)	p
Sex						
Male	118	9 (7.6%)	1.0		1.0	
Female	93	16 (17.2%)	2.5 (1.1 − 6.0)	0.04	2.9 (1.1 − 7.5)	0.02
Age category (years)						
29- 39	75	8 (10.7%)	1.0		1.0	
40- 51	135	17 (12.6%)	1.2 (0.5 − 3.0)	0.68	1.2 (0.5 − 3.1)	0.70
Census region						
AUA	46	3 (6.5%)	1.0		1.0	
NWU	159	22 (13.8%)	2.3 (0.7 − 8.1)	0.19	2.0 (0.5 − 7.5)	0.32
ROU	6	0 (0.0%)	-	-	-	-
Education level						
Primary or lower	19	2 (10.5%)	1.0		1.0	
Secondary completed	109	11 (10.1%)	1.0 (0.2 − 4.7)	0.95	0.9 (0.2 − 4.7)	0.89
University completed	83	12 (14.5%)	1.4 (0.3 − 7.0)	0.65	2.0 (0.4 − 10.2)	0.43
BMI category (kg/m^2)						
< 26 (healthy weight)	15	2 (13.3%)	1.0		1.0	
26- 32 (overweight)	36	4 (11.1%)	0.8 (0.1 − 5.0)	0.82	0.9 (0.1 − 5.9)	0.90
> 32 (obesity)	159	19 (12.0%)	0.9 (0.2 − 4.2)	0.87	0.8 (0.2 − 4.4)	0.83

Table 3: Bivariate and multivariable associations between study variables and awareness of hypertension diagnosis
* Numbers may not sum to total (n= 212) due to missing data.
† Awareness was based on participant report of a prior hypertension diagnosis.
¶ OR adjusted for all other variables presented (sex, age category, census region, education level, and BMI category).

seeking behavior. No other significant correlates of awareness were identified, suggesting the need to look beyond demographic characteristics. Several other factors influence how patients interact with healthcare systems: limited access to screening, NCD counseling, or lack of communication of test results may impede diagnosis;[33] additionally, in the Pacific healthcare is often sought late in the disease continuum with familial or societal obligations prioritized.[40] On a structural level, a limited workforce has challenged the monitoring of NCDs,[11,41] highlighting the importance of task-shifted or community-based care.[42]

While lack of awareness was a concern, medication use was widespread among those reporting a diagnosis, representing an improvement since 2002-2003, when hypertension medication use was 33.3% among diagnosed Samoan males (18-44 years) and 46.7% among females.[22] Medication use indicates availability, which is often challenging in LMIC settings,[43−45] and at least some level of accessibility. Control of both NCDs, however, was poor, suggesting that medication use at the time of the survey may not reflect continuity in taking medications long-term or consistency in engaging with the healthcare system. For many patients, interacting with the health system, particularly the main hospital situated in Apia, may involve considerable travel time, disruption to daily life, or time away from employment. Suboptimal control may also be associated with local beliefs that NCDs are cyclical rather than chronic in nature or that medications can be discontinued once patients "feel better."[37] Although medications are heavily subsidized by the Samoan government, financial barriers to sustained health system engagement and medication use are often cited.[37] Since the small number of participants who exhibited control of their condition in this study prohibited formal analyses, further research is needed to better document factors impacting NCD control in this setting.

Population-level interventions in the Pacific are placing increased emphasis on improving primary care screening campaigns, regular surveillance, and NCD self-management.[42] More widespread national screening and surveillance campaigns that include annual physicals for at-risk groups, as well as programs that leverage village and district nurses for community-based primary care may be critical steps towards reducing gaps in the continuum of care. Previously, a randomized controlled trial that tested a primary care-based nurse-community health worker intervention in American Samoa showed that targeted delivery of education on healthy eating, medication use, and self-monitoring, improved HbA1c among intervention recipients.[46] Benefits did not extend, however, beyond the end of the trial, indicating that longer-term efforts that prioritize sustainability within existing health infrastructure are needed[47] Current efforts to reinvigorate village-based care, including broad implementation of the recently introduced PEN *Fa'a Samoa* program,[37,42] an initiative that emphasizes early detection of NCDs, referral to local care, and increasing awareness surrounding risk factors, may be an effective first step. While most population-level interventions and policies still favor an older adult population, the PEN Fa'a Samoa program is targeting all adults >20 years of age, bearing promise for future efforts to focus on a younger, high-risk segment of the population.[37] Without an additional focus on ensuring all those screened are engaged in treatment initially and remain so, however, this approach may have little impact on disease control. Repetition of cascade of care analyses in coming years may serve as a useful evaluation tool.

Several limitations of this work should be noted. As we describe above, our prevalence estimates cannot be generalized nationally due to our convenience sampling and the exclusion of the most rural census region, nor beyond Samoa. Because the purpose of the recruitment was not NCD screening, we believe that any bias towards participation among those seeking blood pressure or blood sugar screening was minimal. The number of participants who met each exclusion category was also not recorded, and the number of participants in some category comparisons, particularly across census regions, was small. We recognize additional challenges of generalizability associated with excluding those on diet and exercise programs, or with significant prior weight loss, although we believe few reported these behaviors. While the higher rate of diabetes observed in rural Upolu compared to other census regions aligns with a trend involving a faster rise in diabetes in rural regions in comparison to urban areas as of 2002[48] we urge caution in interpreting this finding given that only 3% of the sample were resident in the rural area. Ideally, hypertension diagnoses result from BP measurements completed on at least two separate occasions; we were limited by the single participant interaction, therefore the prevalence of hypertension should, again, be interpreted with caution. There are several approaches to constructing cascades of care,[49] and we used a fixed denominator rather than a conditional or time-series analysis. Specifically, our study used prior diagnosis (awareness), as the first step in the care continuum and did not assess whether participants had ever received BP or diabetes screening. When Fraser-Hurt et al. conducted a similar hypertension-focused study in Samoa in 2018,[35] they began their cascade with screening and documented significant deficits in BP screening rates, which may indicate further challenges of resource availability and use. Finally, our definition of awareness was based on the question "Has a doctor ever told you that you have hypertension or diabetes? (separate questions for each condition)" If the question was interpreted literally, it may have overlooked diagnoses by nurses, other allied health professionals, or research-based screening like ours, thereby overestimating deficits in awareness.

We believe, however, this was unlikely given the comparable estimates presented by Fraser-Hurt et al (2020).[35]

The chronic disease burden in Samoa demands urgent action and investment in preventative and primary care. Substantial losses in both diabetes and hypertension care cascades were observed at the awareness stage. Widespread treatment use among those who were aware of their diabetes and hypertension, indicates that targeted interventions should be directed towards increasing awareness and subsequent management once on a treatment regimen. Primary healthcare delivery aimed at early detection should yield significant gains in addressing disease awareness in Samoa and may mitigate the challenges that other resource-strained settings face in burgeoning NCD crises.

Data sharing statement
Individual participant data and data dictionaries that underlie the results reported here, will be made available upon reasonable request following publication of the article, and after de-identification. Data will be available for 5 years following article publication. Data may be shared with researchers who provide a methodologically robust and sound proposal. Proposals and requests for data sharing should be directed to the corresponding author.

Contributors
NLH, STM, and LCL designed the study. All authors contributed to research execution. LCL, NLH, and STM were responsible for data analysis and manuscript writing. LCL, NLH, and STM accessed and verified the underlying data. All authors reviewed and approved the manuscript.

Declaration of Competing Interest
The authors have no conflicts of interest to disclose.

Supplementary materials
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