

Undiagnosed diabetes, hypertension, and hypercholesterolaemia in an overweight or obese population: implications for cardiovascular disease risk screening programme

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(Index words: undiagnosed diabetes, undiagnosed hypertension, undiagnosed hypercholesterolaemia, cardiovascular disease risk, screening)

Abstract

Introduction Establishing the burden of undiagnosed CVD risk factors is critical to monitoring public health efforts related to screening and diagnosis.

Objective To assess the proportion and determinants of undiagnosed diabetes, hypertension, and hypercholesterolaemia, among overweight or obese adults.

Methods A sample of 1200 participants aged 35-64 years with a BMI ≥ 25 kg/m² was selected from the Colombo district. Data were collected through a questionnaire, anthropometry, blood pressure measurement, and blood sampling for fasting plasma glucose, HbA1c, and lipid profile. Undiagnosed diabetes, hypertension, and hypercholesterolaemia were defined as fasting plasma glucose ≥ 126 mg/dL or HbA1c $\geq 6.5\%$; systolic blood pressure ≥ 140 mmHg or diastolic blood pressure ≥ 90 mmHg; total cholesterol ≥ 240 mg/dl respectively, in a person without a previous diagnosis. Multiple logistic regression analyses were carried out to identify determinants.

Results The prevalence (95%CI) of diabetes was 28.0% (25.5, 30.5), hypertension, 33.4% (30.7, 36.1) and hypercholesterolaemia, 31.9% (29.2, 34.5). The proportion of undiagnosed diabetes was 13.8% (11.9, 15.8), undiagnosed hypertension 11.3% (9.5, 13.1), and undiagnosed hypercholesterolaemia 17.8% (15.6, 19.9). Undiagnosed cases accounted for almost half of all diabetes cases, one-third of all hypertension cases, and more than half (56%) of all high cholesterol cases. The key determinants for undiagnosed CVD risk were: male sex, low or middle income, rural residence, and relatively younger age.

Conclusion CVD screening programmes should be tailored to target populations based on these determinants and provide basic diagnostic facilities in all

health centres. The 'proportion undiagnosed' in the population may be a useful indicator to evaluate their effectiveness.

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Introduction

Cardiovascular diseases (CVD) are the leading cause of death globally. In 2015, there were an estimated 422.7 million cases and 17.9 million deaths due to CVD in the world [1]. According to the Global Burden of Disease 2016 Study, CVDs accounted for 20% of the total disease burden in women and 24% of the total burden in men [2]. Ischaemic heart disease, causing 174 million Disability Adjusted Life Years (DALY), remained the leading cause of total global CVD burden. In Sri Lanka, ischaemic heart disease is the leading cause of death and was responsible for 31.0 deaths per 100,000 population in 2017 [3]. If the health systems fail to respond to this burden using a scientific approach, the Sustainable Development Goal (SDG) target of reducing premature deaths due to noncommunicable diseases by one-third by 2030 will be far from reality [2,4].

There are multiple risk factors that contribute to cardiovascular risk. Abnormal lipids, smoking, hypertension, diabetes, abdominal obesity, psychosocial factors, low consumption of fruits and vegetables, high alcohol consumption, and physical inactivity account for most of the CVD risk worldwide [5]. The WHO emphasizes that people who are at high cardiovascular risk due to the

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presence of one or more risk factors such as hypertension, diabetes, hyperlipidaemia or already established disease, need early detection and management using counselling and medicines, as appropriate [6].

In Sri Lanka, Healthy Lifestyle Centers (HLC) were established by the Ministry of Health in 2011 as a noncommunicable disease (NCD) screening service at primary health care institutions. By the first quarter of 2016, the cumulative percentage of the target population (aged 40-65 years) screened for NCD risk factors at HLC was 25.5%, with a lower proportion of men than women [7]. This percentage is still low in contrast to the rising trend of CVD, and recent improvement in availability and readiness of services at the HLC [3,8,9]. With this low coverage, there is a high chance that many individuals in the population are living with CVD risk factors such as diabetes, hypertension, and hypercholesterolaemia without knowing their presence. Thus, establishing the burden of undiagnosed CVD risk factors is critical to monitoring public health efforts related to screening and diagnosis [10].

It has been previously described by the Sri Lanka Diabetes Cardiovascular Study (SLDCS 2005-06) that the prevalence of undiagnosed diabetes was 3.9% in the adult population. The undiagnosed diabetes accounted for one-third of all diabetes cases [11]. There are no recently published data regarding the proportion of undiagnosed as a percentage of the population. Furthermore, any previous in-country studies for undiagnosed hypertension or hypercholesterolaemia are not available. Little is known about the type of people who are more likely to be undiagnosed for CVD risk factors. Potential determinants for undiagnosed CVD risk factors would be useful in identifying target populations for efficient screening. In this study, we aimed to assess the proportion and determinants of undiagnosed diabetes, hypertension, and hypercholesterolaemia, among overweight or obese adults aged 35-64 years from the Colombo district in Sri Lanka.

Methods

Study population

The present study included cross-sectional data of the baseline assessment of a randomized controlled trial designed to evaluate the effects of a mHealth nutrition and lifestyle intervention on CVD risk reduction in the Colombo district. Individuals aged 35-64 years with a body mass index (BMI) of 25 kg/m² or higher were included. Currently, pregnant or breastfeeding mothers and anyone who has a recent weight loss of at least 5% in the preceding six months was excluded. The estimated sample size was 1200 to test a reduction in 10-year CVD risk among participants by one-third, following the intervention.

Participants were selected in two stages from the 15 MOH areas in the Colombo Regional Director of Health

Services area. In the first stage, 5 to 6 clusters (Grama Niladhari Divisions) within each MOH area were selected randomly. In the second stage, data collectors visited about 30-35 households located together within each selected cluster. The potential participants were screened for eligibility (as described above), and BMI was calculated by measuring weights and heights during this process. Only one eligible participant was chosen randomly from a given family. Of the 2518 participants screened for eligibility, 1318 were excluded due to non-eligibility. A detailed methodology is available elsewhere [12].

The project obtained ethics clearance from the Ethics Review Committee of the Faculty of Medicine, University of Colombo (Ref. No: EC-16-061).

Measurements

Basic sociodemographic data (age, sex, ethnicity, education level, employment, income, and residence) were gathered through a questionnaire-based interview. Self-reported physician diagnoses of diabetes, hypertension, and hypercholesterolaemia were verified through medical records or prescriptions. Height and weight were measured using standard anthropometric equipment to the nearest 0.1 cm and 0.1 kg, respectively (Seca 213 and 813, Hamburg, Germany). Blood pressure was measured three times at the right arm in sitting position after a fifteen-minute rest using a validated digital blood pressure apparatus (Omron HEM 7320, Kyoto, Japan). The average of the second and third measurements was used. Blood samples (6 ml of blood per person) were drawn in 12-hour fasting state and sent to an accredited laboratory within an hour and tested using the recommended methods – fasting plasma glucose using glucose oxidase method (Randox Imola, UK), HbA1c using high-performance liquid chromatographic assay (Bio-Rad D10, USA), and total cholesterol using cholesterol oxidase method (Randox Imola, UK).

Definitions of diagnosed and undiagnosed risk factors

Undiagnosed diabetes was defined as elevated levels of either fasting glucose (≥ 7.0 mmol/L [≥ 126 mg/dL]) or HbA1c ($\geq 6.5\%$) measured in the same blood sample in a person without a previous diagnosis of diabetes. Diagnosed diabetes was defined as a self-reported physician diagnosis of diabetes or receiving medication for diabetes. Persons defined as not having diabetes included those with fasting glucose < 126 mg/dL and HbA1c $< 6.5\%$. The classification was based on the American Diabetes Association (ADA) diagnostic criteria [13].

Undiagnosed hypertension was defined as elevated levels of systolic blood pressure (≥ 140 mmHg) or diastolic blood pressure (≥ 90 mmHg), measured in a person without a previous diagnosis of hypertension. Diagnosed hypertension was defined as a self-reported physician diagnosis of raised blood pressure or current use of

antihypertensive medication. Persons defined as not having hypertension included those with systolic and diastolic blood pressure <140 mmHg and <90 mmHg respectively.

Undiagnosed hypercholesterolaemia was defined as elevated levels of total cholesterol (≥ 240 mg/dl) measured in a person without a previous diagnosis of hypercholesterolaemia. Diagnosed hypercholesterolaemia was defined as a self-reported physician diagnosis of raised cholesterol or receiving medication for it. Persons defined as not having hypercholesterolaemia included those with normal total cholesterol (<240 mg/dl).

For self-reported physician diagnosis of any of the conditions, verification was done by review of previous medical records, laboratory reports, or prescriptions.

Statistical analyses

Percentages with 95% confidence intervals were calculated for undiagnosed, diagnosed, and not having disease out of the total investigated. The undiagnosed CVD risk conditions (diabetes, hypertension or hypercholesterolemia) were expressed as a percentage of all participants. It reflects the probability that a person in the defined population to have the undiagnosed risk condition. Undiagnosed percentages were disaggregated by biological and sociodemographic variables.

Multiple logistic regression analyses were carried out

using undiagnosed as the dependent variable (undiagnosed=1; previously diagnosed =0) while entering all biological and socioeconomic variables as categorical covariates in a single step. The purpose of the regression analysis is to estimate the magnitude of effect and significance of independent variables for predicting the 'undiagnosed' in contrast to the 'previously diagnosed' after adjusting for confounding variables. Thus, the category of 'not having disease' was excluded in the regression models. Adjusted odds ratios (95% confidential interval) are presented to indicate the magnitude of risk (odds of being undiagnosed) with $p < 0.05$ as the level of significance. SPSS version 20.0 was used for statistical analysis.

Results

Sociodemographic characteristics of participants

Table 1 presents the distribution of participants according to selected biological and sociodemographic characteristics. Of the 1200 participants, 64% were female, 60% aged below 50 years, and 70% were overweight with BMI 25-29.9 kg/m². The proportions of Sinhalese, Tamil, and Moor ethnicities were 95.5%, 2.1%, and 2.2% respectively. More than two-thirds (67.4%) had completed GCE (O/L) or above. Approximately 27% were not engaged in any employment, and 12% reported a monthly household income of less than 20,000 LKR. Seventy percent live in urban areas.

Table 1. Biological and sociodemographic characteristics of participants (n=1200)

Characteristic		No.	%
Sex	Male	435	36.2%
	Female	765	63.8%
Age category (years)	35-39	196	16.3%
	40-44	264	22.0%
	45-49	255	21.2%
	50-54	238	19.8%
	55-59	157	13.1%
	60-64	90	7.5%
BMI category (kg/m ²)	25.00-27.49	488	40.7%
	27.50-29.99	345	28.8%
	30.00-32.49	193	16.1%
	32.50-34.99	90	7.5%
	35.00-39.99	68	5.7%
	40.00 & above	16	1.3%
Ethnicity	Sinhalese	1146	95.5%
	Tamil	25	2.1%
	Moor	27	2.2%
	Other	2	0.2%

(Continued)

Characteristic		No.	%
Highest level of education	None or Primary (Grades 1-5)	54	4.5%
	Secondary (Grades 6-11)	338	28.2%
	GCE OL passed	272	22.7%
	GCE AL passed	354	29.5%
	Degree and above	182	15.2%
Nature of employment	Full-time public sector	491	40.9%
	Full-time private sector	132	11.0%
	Self-employed/own account employer	176	14.7%
	Casual employment	14	1.2%
	Unpaid family work	42	3.5%
	Retired	18	1.5%
	Unemployed	327	27.2%
Monthly income (LKR)	<20,000	142	11.8%
	20,000-39,999	495	41.2%
	40,000-59,999	357	29.8%
	60,000-79,999	111	9.2%
	80,000 & above	95	7.9%
Residential sector	Rural	360	30.0%
	Urban	840	70.0%

Diabetes, hypertension, and hypercholesterolaemia

In this subpopulation, the prevalence (95% CI) of diabetes was 28.0% (25.5, 30.5), hypertension, 33.4% (30.7, 36.1) and hypercholesterolaemia, 31.9% (29.2, 34.5).

As illustrated in Figure 1, the proportion (95% CI) undiagnosed diabetes was 13.8% (11.9, 15.8), undiagnosed hypertension 11.3% (9.5, 13.1), and undiagnosed hyper-

cholesterolaemia 17.8% (15.6, 19.9). The proportion (95% CI) of previously diagnosed diabetes was 14.2% (12.2, 16.1), hypertension 22.1% (19.7, 24.4) and hypercholesterolaemia 14.1% (12.1, 16.1). Undiagnosed cases accounted for almost half of all diabetes cases, one-third of all hypertension cases, and more than half (56%) of all high cholesterol cases.

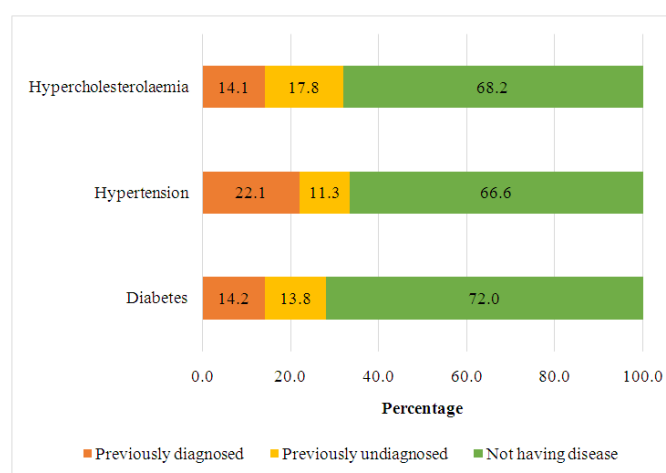


Figure 1. Diagnosed and undiagnosed diabetes, hypertension and hypercholesterolaemia (n=1200).

Percentages and 95% CI:

Previously diagnosed: diabetes 14.2% (12.2, 16.1); hypertension 22.1% (19.7, 24.4); hypercholesterolaemia 14.1% (12.1, 16.1).

Previously undiagnosed: diabetes 13.8% (11.9, 15.8);

hypertension 11.3% (9.5, 13.1); hypercholesterolaemia 17.8% (15.6, 19.9).

Determinants of undiagnosed risk factors

The results of multiple logistic regression analyses are presented in Tables 2 to 4. The odds ratios indicate the odds of being undiagnosed for a given predictor variable when adjusted for all other variables in the table.

People living in rural areas (AOR=2.058), having

income less than LKR 60,000 per month (AOR ranged from 2.671 to 2.813 for different income groups), or who were marginally obese (AOR=3.056 for BMI 30.00-32.5 kg/m²) were more likely to be undiagnosed with diabetes (Table 2). Men were almost twice (AOR=2.034) as likely to be undiagnosed with hypertension than women. There was no urban/rural difference in undiagnosed hypertension.

Table 2. Determinants of undiagnosed diabetes: multiple logistic regression analysis

Characteristic		Undiagnosed diabetes ^a %	P value ^b	Adjusted OR	95% Confidence Interval	
Sex	Male	13.8%	0.085	0.624	0.364	1.067
	Female	13.9%	-	-	-	-
Age category (years)	60-64	20.0%	0.180	0.490	0.172	1.391
	55-59	16.6%	0.022	0.332	0.129	.854
	50-54	16.0%	0.024	0.356	0.145	.873
	45-49	14.9%	0.078	0.443	0.180	1.095
	40-44	10.2%	0.809	0.882	0.319	2.436
	35-39	9.7%	-	-	-	-
BMI category (kg/m ²)	40.00 & above	25.0%	0.125	5.831	0.611	55.614
	35.00-39.99	17.6%	0.365	1.545	0.603	3.962
	32.50-34.99	16.7%	0.090	2.212	0.883	5.537
	30.00-32.49	16.6%	0.002	3.056	1.523	6.135
	27.50-29.99	15.1%	0.132	1.518	0.881	2.614
	25.00-27.49	10.5%	-	-	-	-
Ethnicity	Moor	33.3%	0.314	1.837	0.563	5.993
	Tamil	16.0%	0.699	1.323	0.319	5.489
	Sinhalese	13.4%	-	-	-	-
Highest level of education	None or Primary	22.2%	0.370	0.558	0.156	1.997
	Secondary	17.2%	0.464	0.688	0.253	1.870
	GCE OL passed	12.5%	0.191	0.519	0.194	1.387
	GCE AL passed	11.6%	0.394	0.682	0.283	1.644
	Degree and above	11.5%	-	-	-	-
Nature of employment	Full-time public sector	13.4%	0.095	1.908	0.893	4.076
	Full-time private sector	13.6%	0.365	1.489	0.630	3.523
	Self-employed / own account employer	15.9%	0.929	0.969	0.479	1.957
	Casual employment	7.1%	0.750	0.662	0.052	8.367
	Unpaid family work	14.3%	0.671	1.324	0.362	4.838
	Retired	22.2%	0.107	4.548	0.720	28.720
	Unemployed	13.1%	-	-	-	-
Monthly income (LKR)	<20,000	19.0%	0.091	2.712	0.853	8.624
	20,000-39,999	14.3%	0.060	2.671	0.960	7.436
	40,000-59,999	15.1%	0.042	2.813	1.037	7.628
	60,000-79,999	3.6%	0.238	0.434	0.109	1.734
	80,000 & above	10.5%	-	-	-	-
Residential sector	Rural	16.1%	0.005	2.058	1.237	3.423
	Urban	12.9%	-	-	-	-

^a As a proportion of total investigated

^b P values are for the adjusted odds ratios based on the multiple logistic regression analyses. The dependent variable was defined as 1 if undiagnosed diabetes and 0 if previously diagnosed diabetes. The odds ratio for a given variable was adjusted for all other co-variables in the table.

Low-income categories did not show significant odds, although the values were somewhat higher for such groups (Table 3). Low and middle-income categories were more likely to be undiagnosed with hypercholesterolaemia (AOR ranged from 3.121 to 3.922 for different income

groups) in contrast to the highest monthly income group (Table 4). The results also indicated that older groups were less likely to be undiagnosed with diabetes and hypercholesterolaemia, independent of other socio-demographic factors.

Table 3. Determinants of undiagnosed hypertension: multiple logistic regression analysis

Characteristic		Undiagnosed diabetes ^a %	P value ^b	Adjusted OR	95% Confidence Interval	
Sex	Male	16.1%	0.007	2.034	1.216	3.401
	Female	8.6%	-	-	-	-
Age category (years)	60-64	10.0%	0.117	0.444	0.161	1.227
	55-59	19.7%	0.708	0.858	0.387	1.906
	50-54	10.1%	0.133	0.539	0.240	1.208
	45-49	12.2%	0.998	1.001	0.451	2.222
	40-44	9.5%	0.702	1.178	0.510	2.722
	35-39	8.2%	-	-	-	-
BMI category (kg/m ²)	40.00 & above	31.2%	0.460	1.663	0.431	6.415
	35.00-39.99	16.2%	0.886	1.064	0.454	2.492
	32.50-34.99	15.6%	0.153	1.812	0.801	4.099
	30.00-32.49	8.8%	0.176	0.630	0.322	1.231
	27.50-29.99	10.4%	0.303	0.752	0.438	1.293
	25.00-27.49	10.9%	-	-	-	-
Ethnicity	Moor	11.1%	0.598	0.684	0.167	2.807
	Tamil	4.0%	0.226	0.267	0.031	2.268
	Sinhalese	11.4%	-	-	-	-
Highest level of education	None or Primary	11.1%	0.367	0.552	0.152	2.008
	Secondary	10.9%	0.216	0.569	0.233	1.389
	GCE OL passed	11.8%	0.321	0.647	0.274	1.529
	GCE AL passed	10.5%	0.114	0.544	0.255	1.159
	Degree and above	13.2%	-	-	-	-
Nature of employment	Full-time public sector	13.8%	0.136	1.757	0.837	3.690
	Full-time private sector	10.6%	0.478	0.734	0.312	1.726
	Self-employed / own account employer	13.1%	0.149	1.717	0.824	3.578
	Casual employment	7.1%	0.859	1.256	0.101	15.686
	Unpaid family work	4.8%	0.751	0.767	0.150	3.928
	Rtired	16.7%	0.738	0.741	0.128	4.305
	Unemployed	7.6%	-	-	-	-
Monthly income (LKR)	<20,000	10.6%	0.262	1.890	0.621	5.745
	20,000-39,999	12.1%	0.086	2.256	0.891	5.713
	40,000-59,999	12.0%	0.492	1.371	0.558	3.372
	60,000-79,999	6.3%	0.416	0.626	0.202	1.939
	80,000 & above	11.6%	-	-	-	-
Residential sector	Rural	9.2%	0.833	0.947	0.572	1.568
	Urban	12.3%	-	-	-	-

^a As a proportion of total investigated

^b P values are for the adjusted odds ratios based on the multiple logistic regression analyses. The dependent variable was defined as 1 if undiagnosed hypertension and 0 if previously diagnosed hypertension. The odds ratio for a given variable was adjusted for all other co-variables in the table.

Table 4. Determinants of undiagnosed hypercholesterolemia: multiple logistic regression analysis

Characteristic		Undiagnosed hypercholesterolemia ^a %	P value ^b	Adjusted OR	95% Confidence Interval	
Sex	Male	17.0%	0.418	.810	0.488	1.347
	Female	18.2%	-	-	-	-
Age category (years)	60-64	23.3%	0.099	0.464	0.186	1.155
	55-59	14.0%	0.010	0.331	0.142	0.771
	50-54	22.3%	0.142	0.573	0.273	1.206
	45-49	16.9%	0.167	0.580	0.268	1.255
	40-44	15.2%	0.130	0.548	.0252	1.194
	35-39	17.3%	-	-	-	-
BMI category (kg/m ²)	40.00 & above	6.2%	0.822	0.724	0.044	12.015
	35.00-39.99	8.8%	0.049	0.333	0.112	0.993
	32.50-34.99	11.1%	0.475	0.700	0.264	1.859
	30.00-32.49	18.7%	0.697	0.887	0.485	1.622
	27.50-29.99	16.5%	0.210	0.728	0.443	1.196
	25.00-27.49	21.1%	-	-	-	-
Ethnicity	Moor	18.5%	0.253	2.684	0.493	14.608
	Tamil	8.0%	0.166	0.300	0.054	1.651
	Sinhalese	18.0%	-	-	-	-
Highest level of education	None or Primary	14.8%	0.511	0.651	0.181	2.341
	Secondary	19.8%	0.778	0.884	0.375	2.085
	GCE OL passed	17.3%	0.868	1.075	0.459	2.519
	GCE AL passed	16.7%	0.867	1.064	0.512	2.213
	Degree and above	17.6%	-	-	-	-
Nature of employment	Full-time public sector	17.7%	0.227	1.518	0.771	2.989
	Full-time private sector	19.7%	0.082	2.075	0.912	4.717
	Self-employed / own account employer	15.3%	0.394	1.357	0.672	2.741
	Unpaid family work	28.6%	0.091	2.642	0.856	8.149
	Retired	11.1%	0.759	1.378	0.178	10.693
	Unemployed	17.4%	-	-	-	-
Monthly income (LKR)	<20,000	23.9%	0.013	3.922	1.340	11.478
	20,000-39,999	16.2%	0.017	3.131	1.223	8.017
	40,000-59,999	19.0%	0.014	3.121	1.261	7.726
	60,000-79,999	18.9%	0.014	3.763	1.306	10.845
	80,000 & above	10.5%	-	-	-	-
Residential sector	Rural	15.6%	0.585	0.878	0.549	1.402
	Urban	18.7%	-	-	-	-

^a As a proportion of total investigated

^b P values are for the adjusted odds ratios based on the multiple logistic regression analyses. The dependent variable was defined as 1 if undiagnosed hypercholesterolaemia, and 0 if previously diagnosed hypercholesterolaemia. The odds ratio for a given variable was adjusted for all other co-variables in the table.

Discussion

This study revealed high proportions of undiagnosed CVD risk factors in an overweight/obese subpopulation, amounting to 13.8% (95% CI: 11.9, 15.8) for diabetes, 11.3% (95% CI: 9.5, 13.1) for hypertension and 17.8% (95% CI: 15.6, 19.9) for hypercholesterolaemia. Undiagnosed cases represent the unseen but clinically important burden of risk factors, with significant concurrent metabolic derangements and a long-term impact on health care use [14,15]. Of the three risk conditions, hypercholesterolaemia was the most undiagnosed condition, whereas hypertension was the least undiagnosed condition. This discrepancy reflects the differences in accessibility and affordability to diagnostic facilities.

According to the global burden of disease analysis, hypertension is the leading single risk factor responsible for preventable global CVD burden. Other risk factors include an unhealthy diet, high total cholesterol, air pollution, tobacco use, high body mass index, high fasting plasma glucose, impaired kidney function, and low physical activity in that order [2]. The present analysis focused on three of those important risk factors which need laboratory testing at a health facility.

In our definition of ‘undiagnosed proportion’, we used the total number investigated as the denominator as opposed to the total number with the respective disease. This definition is more relevant in community screening programmes since it reflects the probability that a person in the population has the disease without her or his knowledge. Such people would continue without treatment until they are detected at a later stage with irreversible complications such as CVD, stroke, or kidney disease. Thus, the proportion ‘undiagnosed’ based on a community sample like in this would be a useful indicator to evaluate the effectiveness of screening programmes in detecting CVD risk in the community.

This study revealed an alarmingly high prevalence of diabetes, hypertension, and hypercholesterolaemia, 28.0%, 33.4%, and 31.9%, respectively. Our findings, together with other available studies, confirm that there is a rapidly rising trend in diabetes, especially in urban settings [11,16-19]. With this trend, the undiagnosed population may rise even faster. According to our findings, undiagnosed diabetes accounted for almost half of all diabetes cases, compared to one-third reported previously [11]. In contrast, undiagnosed hypertension accounted for one-third of all hypertension cases in the present study compared to half reported previously [17].

We identified some relevant determinants of undiagnosed CVD risk factors through regression analyses while addressing the confounding effects. The key determinants for undiagnosed CVD were: male sex, low or middle income, rural residence, and relatively younger age. Living in a rural area as a predictor for undiagnosed DM could be attributed to a lack of

motivation or low accessibility to blood glucose testing services in a rural setting compared to the urban. The costs also play an independent role in undiagnosed diabetes, indicating less affordability. Thus, it is important to ensure that all primary health care facilities in a rural setting will have testing facilities, and people are motivated to attend such services.

Male sex as a predictor for undiagnosed hypertension indicates that men are ignorant about the screening facilities compared to women. Employed status is a major barrier that prevents men from attending these services during working hours. However, there were no differences across the type of employment in the present analysis. Our findings suggest the need to encourage and provide provisions for men in accessing services for blood pressure checking, preferably at the workplace or during non-working hours at HLC.

Lower household income as a predictor of undiagnosed diabetes and elevated cholesterol indicates an economic reason for poor detection. Concerning cholesterol, the odds are very high even for middle-income groups compared to the highest income group. This raises concerns whether testing facilities are not readily available at the government health facilities and people cannot afford high cost for testing lipid profiles at private sector laboratories. However, it is important to provide this service in all state health facilities or subsidize it for low-income groups.

Our analysis found that older ages were less likely to be undiagnosed compared to younger ages. This is explained by the frequent health care seeking by the elderly. The age-specific analyses show a rapid increase in obesity, diabetes, and hypertension during the 4th decade of life [20]. Therefore, screening programmes should target lower ages, especially those around 40 years.

A mere increase in coverage of screening at primary health care facilities does not guarantee that it would capture many of those with CVD conditions in the population. If the attendees are of lower risk, then there will not be many positives despite a high screening coverage. Therefore, screening programmes should adopt a high-risk screening strategy, where relevant, focusing on the determinants of undiagnosed CVD risk factors. Tailoring screening programmes according to contexts such as risk level to reach those most in need has been recommended in a review on effectiveness and uptake of screening programmes for coronary heart disease and diabetes globally [21]. In Sri Lanka, there is a promising initiative by the state health services to enhance primary health care services in the recent past. The cluster care system with defined catchment areas for each PHC aims for high coverage of screening and detection of CVD risk in the population [22]. We suggest targeting populations based on the determinants highlighted by this study to enhance its efficiency. Thereby, detection rates of diabetes

mellitus, hypertension, dyslipidaemia can be improved in cluster catchment areas. Such an approach would contribute to reducing premature deaths due to cardiovascular diseases in the country.

The present study has a few limitations. The sample of the study is representative, however, the representativeness was affected somewhat due to 2 reasons: selection of houses located together within the cluster; and less availability of males than females during home visits. However, males were approached at their workplace or home during non-working days. Our study population is different from the general population since we selected individuals with a BMI over 25 kg/m². This resulted in a sex imbalance with a higher proportion of females in the sample, which was addressed in the regression analysis by adjusting for sex and other covariates. The study did not include access to health care services as a key determinant in the analyses.

Conclusions

The present study revealed high proportions of undiagnosed diabetes, hypertension, and hypercholesterolaemia in an overweight/obese population. Male sex, low or middle income, rural residence, and relatively younger age were the key determinants for undiagnosed CVD risk factors. The CVD screening programmes should be tailored to target populations based on these determinants and provide basic diagnostic facilities in all health centres. The 'proportion undiagnosed' in the population may be a useful indicator to evaluate the effectiveness.

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