Article

Factors Associated With Prediabetes and Diabetes Among Public Employees in Northern Ethiopia

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Abstract

The increasing burden of diabetes mellitus is one of the major public health challenges in African countries, including Ethiopia. This is the first study aimed to identify factors associated with prediabetes and diabetes defined by both fasting blood glucose and glycated hemoglobin in Ethiopians. We analyzed data of a cross-sectional survey (1372 adults aged 25-64 years) conducted between October 2015 and February 2016; multinomial logistic regression models were applied. Abdominal obesity, total cholesterol, and non–high-density lipoprotein cholesterol were independently associated with prediabetes and diabetes in both sexes. Increased triglycerides and religious fasting practices were independently associated with prediabetes and diabetes only in men; hypertension was associated with prediabetes and diabetes only in women, while high-density lipoprotein cholesterol was not associated with prediabetes and diabetes in either sex. Sex differences in the association of triglycerides, hypertension, and dietary habit suggest that different approaches of lifestyle modification may be required for men and women.

Keywords

diabetes, glycated hemoglobin, HbA1c, non-HDL cholesterol, prediabetes, sex difference

What We Already Know

- Prevalence of diabetes in Ethiopia is much higher than the average of sub-Saharan Africa; an even higher prevalence was reported from our previous survey.
- Factors associated with diabetes were not consistent among previous studies and not well elucidated in Ethiopia.

What This Article Adds

- Non–high-density lipoprotein cholesterol was found to be a potential risk factor of prediabetes and diabetes in Ethiopia.
- Sex difference was found in the association of prediabetes and diabetes with triglycerides, hypertension, and religious fasting practice.

Introduction

Diabetes is an emerging public health challenge in Africa, in which estimated prevalence was 4.2% in 2017, although over two thirds of them were undiagnosed.[1] The prevalence of diabetes in Ethiopia, the second populous country in Africa, was estimated at 7.5% in 2017, nearly twice as high as the average prevalence of the African region.[1] The increasing burden of diabetes in Ethiopia might be related to the urbanization and lifestyle changes during the rapid economic growth in the past decade.[2-4]

Epidemiological studies of known risk factors of raised blood glucose, such as obesity and dyslipidemia, were still limited in number in African countries including Ethiopia.[2,5-7] A nationwide epidemiological survey following the standard procedure of the World Health Organization (WHO) was conducted in 2015 in Ethiopia, and reported that the prevalence of diabetes was 3.5% in men and 3.0% in women.[8,9] The study also reported that increased waist circumference, waist-hip ratio, and raised total cholesterol were associated with diabetes. Two community-based studies in rural areas in Ethiopia reported that

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increased body mass index (BMI) was not significantly associated with diabetes,[10,11] while studies conducted in the capital city, Addis Ababa, reported the significant association between increased BMI and diabetes.[12] Magnitudes of prediabetes and diabetes in Ethiopia in previously conducted studies were assessed using single criteria, fasting blood glucose (FBG), while using combined diagnosis criteria, FBG and glycated hemoglobin (HbA1c), is recommended.

We conducted a cross-sectional survey targeting public employees in Mekelle, a regional capital city in northern Ethiopia. Although it is one of the most populous cities in Ethiopia, its urban population had not been included in other previous epidemiological studies related to diabetes. We measured both FBG and HbA1c and found that the prevalence of diabetes was 13.0% in men and 5.9% in women, much higher than those of the 2015 nationwide survey.[8,9] We have published a profile paper reporting the descriptive statistics of diabetes and other common risk factors of noncommunicable diseases[13]; however, associations of prediabetes and diabetes with other factors have not been elucidated. The current study aimed to examine factors associated with prediabetes and diabetes or their potential risk factors among public employees living in an urban area in northern Ethiopia.

Methods

Study Design and Data Collection

We used the data from our previous epidemiological study conducted between October 2015 and February 2016 in a regional capital city in northern Ethiopia. The survey was designed to cover a wide range of government employees aged 25 to 64 years working in offices of various public services. We mostly followed the WHO standard procedure[14] for the data collection with slight modifications as described elsewhere.[13] In brief, we conducted face-to-face interviews using the standard questionnaire translated into the local language, Tigrina, and added some questions such as religious fasting practice. Anthropometric measurements were taken following the WHO guideline, and portable analyzers were used to measure FBG, total cholesterol, high-density lipoprotein (HDL) cholesterol, triglycerides, and HbA1c. Excluding pregnant women, those aged under 25 years or over 64 years, and 5 subjects missing both FBG and HbA1c data, valid data of 1372 subjects (817 men and 555 women) were statistically analyzed. The total number was greater than the necessary sample size, 1257, which was calculated prior to the survey using the single population proportion formula $[n = [Z^2 * p(1 - p)]/e^2]$ by assuming a 95% confidence interval ($Z = 1.96$) width of 3% ($e = 0.015$) and proportion (p) of diabetes 8% according to previous studies.

Variables

Glycemic status of the subjects was categorized into three groups using combined diagnosis criteria defined by American Diabetes Association. Diabetes was defined as FBG ≥7.0 mmol/L (126 mg/dL) or HbA1c ≥6.5% or currently on treatment. Prediabetes was defined as FBG = 5.6 to 6.9 mmol/L (100-125 mg/dL) or HbA1c = 5.7% to 6.5% subsequently.[15] Normal blood glucose was defined as FBG <5.6 mmol/L (100 mg/dL) and HbA1c <5.7%.

Quartiles were applied to categorize variables of triglycerides, total cholesterol, HDL cholesterol, and non-HDL cholesterol. We included non-HDL cholesterol but not low-density lipoprotein (LDL) cholesterol, because the prevalence of raised triglycerides was high in this population[13]; thus, LDL cholesterol calculated by the Friedewald equation might be inaccurate.[16] Moreover, raised non-HDL cholesterol was reported to be a better predictor of cardiac diseases than LDL cholesterol, particularly among those with raised triglycerides.[17]

Hypertension was defined as systolic blood pressure (SBP) ≥140 mmHg and/or diastolic blood pressure (DBP) ≥90 mmHg, or currently taking antihypertensive medication. Prehypertension was classified as SBP/DBP = 120/80 to 139/89 mmHg.[18]

Body mass index was calculated as bodyweight in kilograms divided by height in meters squared. Overweight and obesity were defined by BMI ≥25 kg/m^2 and ≥30 kg/m^2, respectively. Abdominal obesity was defined as waist circumference ≥94 cm for men and ≥80 cm for women. Waist-to-hip ratio was calculated as waist circumference divided by hip circumference, and large waist-hip ratio was defined as ≥0.90 for men and ≥0.85 for women.[19]

Education levels were divided into three groups: primary school or lower, secondary school, and college or higher. Annual income was categorized into four groups: <500, 500 to 1000, 1001 to 1500, and >1500 US dollars per adult. Alcohol drinking was divided into three groups: <1, 1 to 2.9, and ≥3 standard drinks per day. Fruit and vegetable intakes were divided into three groups: <1, 1 to 2.9, and ≥3 servings per day. Physical activities were categorized into three levels based on WHO criteria: <600, 600 to 2999, ≥3000 metabolic equivalent minutes (MET-minutes) per week.[20]

Statistical Analysis

Statistical analyses of the current study were performed using Stata Statistical Software version 12.1 (Stata Corp). Means ± standard deviations were presented for continuous variables, excepting those with a skewed distribution, for which medians (interquartile ranges) were presented. Categorical variables were presented as proportions. Differences in means and medians across three categories of glycemic status were tested using analysis of variance (ANOVA) and Kruskal-Wallis test, respectively. Chi-squared test was used for comparison of categorical variables.

Multinomial logistic regression models were used to analyze the association between various factors and the outcome variable of glycemic status, namely, normal (reference), prediabetes, and diabetes. Factors of age, education, annual

income, religious fasting, smoking, alcohol drinking, fruit and vegetable intake, physical activity, hypertensive level, and obesity indices (BMI or waist circumference) were included in the models as independent variables and mutually adjusted for each other. For the association between glycemic status and lipids, three different models were developed: Model 1 adjusted for age; Model 2 adjusted for all aforementioned factors except obesity indices; and Model 3 adjusted for BMI in addition to Model 2. Adjusted odds ratios (OR) and 95% confident intervals (CIs) derived from the models were reported. Trend associations with prediabetes and diabetes were assessed by assigning ordinal numbers to each level of the categorical variables, and treating them as continuous variables in the regression models. All statistical tests were 2-sided, and $P < .05$ were considered statistically significant.

Ethical Considerations

This study was approved by the Bioethics Review Committee of Nagoya University School of Medicine, Japan (Approval No. 2014-0107), and the Institutional Review Board of Mekelle University College of Health Sciences, Ethiopia. All procedures performed in this study were in accordance with the Ethical Guidelines for Medical and Health Research Involving Human Subjects that enforced by the Ministry of Health, Labour and Welfare, Government of Japan, and with the 1964 Helsinki Declaration and its later amendments.

Results

Table 1 shows characteristics of normal, prediabetes, and diabetes subjects by gender. Overall mean age was 39.5 years (men: 40.3 years; women: 38.3 years), and the prevalence of prediabetes and diabetes was 37.5% (men: 40.8%; women: 32.5%) and 10.2% (men: 13.1%; women: 5.9%), respectively. Both men and women with prediabetes or diabetes were significantly older, and more likely to have higher BMI, waist circumference, waist-to-hip ratio, SBP, DBP, total cholesterol, and non-HDL cholesterol, and lower HDL cholesterol. Men with prediabetes and diabetes were significantly having higher triglycerides, and more likely to be ever smokers and nonobservers of religious fasting. There were no significant differences among subjects with or without prediabetes or diabetes in education levels, annual income, alcohol drinking, fruit and vegetable intakes, and physical activities.

Table 2 shows ORs and 95% CIs of factors associated with prediabetes and diabetes, excepting biochemical factors. BMI increase was significantly associated with prediabetes and diabetes both in men and women (P for trend $<.001$). Increased waist circumference was significantly associated with prediabetes in both men and women (men, OR = 2.60, 95% CI = 1.70-4.00; women, OR = 2.61, 95% CI = 1.50-4.54), and with diabetes only in men (OR = 3.41, 95% CI = 1.89-6.11). Increased waist-to-hip ratio was significantly associated with prediabetes in both men and women (men, OR = 1.74, 95% CI = 1.19-2.55; women, OR = 2.78, 95% CI = 1.66-4.67), and with diabetes only in men (OR = 2.48, 95% CI = 1.32-4.69). The increase of blood pressure levels was significantly associated with prediabetes and diabetes only in women (P for trend $<.05$). The increase of fruit and vegetable intakes was significantly associated only with diabetes in women (P for trend =.01). Religious fasting was significantly associated with diabetes in men (OR = 1.88, 95% CI = 1.07-1.15). Educational levels, annual income, and physical activities showed insignificant associations with prediabetes and diabetes both in men and women.

Table 3 shows ORs (per 1-quartile increase) and 95% CIs of prediabetes and diabetes for triglycerides, total, HDL, and non-HDL cholesterols. Quartiles of triglycerides are as follows: Q1 = 1.2, Q2 = 1.7, and Q3 = 2.5 mmol/L in men; and Q1 = 1.4, Q2 = 2.3, and Q3 = 4.0 mmol/L in women; of total cholesterol are as follows: Q1 = 3.9, Q2 = 4.5, and Q3 = 5.2 mmol/L in men; and Q1 = 3.9, Q2 = 4.5, and Q3 = 5.2 mmol/L in women; of HDL cholesterol are as follows: Q1 = 0.8, Q2 = 0.9, and Q3 = 1.1 mmol/L in men; and Q1 = 0.9, Q2 = 1.1, and Q3 = 1.3 mmol/L in women; of non-HDL cholesterol are as follows: Q1 = 2.9, Q2 = 3.6, and Q3 = 4.3 mmol/L in men; and Q1 = 2.8, Q2 = 3.3, and Q3 = 4.0 mmol/L in women. Raised triglycerides were significantly associated with prediabetes (OR = 1.33, 95% CI = 1.11-1.58) and diabetes (OR = 1.61, 95% CI = 1.22-2.13) in men but not in women. The increase of total cholesterol was significantly associated with prediabetes (men, OR = 1.28, 95% CI = 1.07-1.53; women, OR = 1.34, 95% CI = 1.11-1.64) and diabetes (men, OR = 1.28, 95% CI = 1.07-1.53; women, OR = 1.34, 95% CI = 1.11-1.64). Non-HDL cholesterol increase was significantly associated with prediabetes (men, OR = 1.30, 95% CI = 1.08-1.56; women = OR: 1.47, 95% CI = 1.19-1.82) and diabetes (men = OR: 1.71, 95% CI = 1.29-2.26; women, OR = 3.28, 95% CI = 1.77-6.10). HDL cholesterol increase was negatively associated with prediabetes and diabetes in men and women when adjusted for age, but the negative association attenuated when BMI and other factors were adjusted.

The post hoc power of the sample size for the current study was calculated to be 0.825 based on the observed results.

Discussion

This is the first study to identify factors associated with prediabetes and diabetes defined by both FBG and HbA1c among Ethiopian adults. This study showed that total cholesterol and non-HDL cholesterol were associated with prediabetes and diabetes, and might be their potential risk factors both in men and women; the association for triglycerides was identified only in men. As far as we learnt, non-HDL cholesterol was found to be a potential risk factor of

Table 1. Characteristics of Subjects by Glycemic Levels and Gender[a].

	Men					Women					
	Normal (n = 376)	Prediabetes (n = 334)	Diabetes (n = 107)	*P*[b]	Total (N = 817)	Normal (n = 341)	Prediabetes (n = 181)	Diabetes (n = 33)	*P*[b]	Total (N = 555)	Both genders (N = 1372)
Age, years	37.3 ± 8.2	41.6 ± 9.4	46.7 ± 8.2	<.001	40.3 ± 9.3	35.8 ± 8.5	41.7 ± 8.9	46 ± 9.8	<.001	38.3 ± 9.3	39.5 ± 9.4
BMI, kg/m^2	21.9 ± 3.5	24.2 ± 4.9	24.5 ± 3.3	.01	23.2 ± 4.3	21.9 ± 4.7	24.8 ± 4.2	26.2 ± 3.4	<.01	23.1 ± 4.7	23.2 ± 4.5
Waist circumference, cm	85.1 ± 9.2	91.5 ± 10.2	95.0 ± 9.3	<.001	89.0 ± 10.4	80.7 ± 11.6	89.3 ± 11.7	95.2 ± 9.5	<.001	84.3 ± 12.5	87.1 ± 11.5
Waist-to-hip ratio	0.88 ± 0.07	0.92 ± 0.09	0.94 ± 0.09	<.001	0.90 ± 0.08	0.83 ± 0.09	0.87 ± 0.08	0.91 ± 0.08	<.001	0.85 ± 0.09	0.88 ± 0.09
SBP, mmHg	119.5 ± 14.2	125.2 ± 16.9	129.5 ± 15.7	<.001	123.1 ± 16.0	111.2 ± 15.3	118.3 ± 16.8	125.9 ± 18.0	<.01	114.4 ± 16.5	119.6 ± 16.8
DBP, mmHg	79.5 ± 9.7	82.6 ± 9.8	84.8 ± 9.2	.01	81.4 ± 9.9	76.3 ± 9.3	79.7 ± 9.7	81.4 ± 8.9	<.001	77.7 ± 9.6	79.9 ± 9.9
Triglycerides, mmol/L[c]	1.4 (1.0)	1.9 (1.5)	2.1 (1.4)	<.001	1.7 (1.3)	2.2 (2.7)	2.3 (2.5)	2.8 (2.6)	.09	2.1 (1.9)	1.9 (1.7)
Total cholesterol, mmol/L[c]	4.2 (1.2)	4.7 (1.4)	5.1 (1.3)	<.001	4.5 (1.3)	4.3 (1.1)	4.7 (1.2)	5.2 (0.9)	<.001	4.5 (1.2)	4.5 (1.3)
HDL cholesterol, mmol/L[c]	0.9 (0.3)	0.9 (0.3)	0.8 (0.3)	<.01	0.9 (0.3)	1.1 (0.4)	1.0 (0.3)	0.9 (0.5)	<.01	1.1 (0.4)	1.0 (0.4)
Education levels, %											
Primary school or lower	8.2	8.4	7.5	.16	8.2	7.6	11.1	12.1	.07	9.0	8.5
Secondary school	12	8.1	4.7		9.4	6.5	7.2	18.2		7.5	8.7
College or higher	79.8	83.5	87.8		82.4	85.9	81.7	69.7		83.5	82.9
Annual income, %											
<500 USD	23.9	19.0	17.0	0.10	21.0	30.6	33.2	37.5	.83	31.9	25.3
500-1000 USD	30.9	24.7	28.3		28.0	30.6	28.8	21.9		29.9	28.8
1001-1500 USD	18.6	24.1	25.5		21.8	17.9	17.7	12.5		17.5	20.1
≥1500 USD	26.6	32.2	29.2		29.2	20.9	19.3	28.1		20.7	25.8
Religious fasting, %	52.8	43.5	33.0	<.01	46.4	69.0	73.9	75.8	.42	71.0	56.5
Ever smoker, %	6.4	9.9	14.9	.02	9.1	1.2	1.1	No exist	.82	1.1	5.8
Alcohol drinking, %											
<1 standard drinks/day	75.4	68.3	76.1	.14	72.3	97.6	97.5	100	.79	97.7	81.3
1-2.9 standard drinks/day	22.1	25.6	19.3		23.4	2.4	2.5	No exist		2.3	15.9
≥3 standard drinks/day	2.5	6.1	4.6		4.3	No exist	No exist	No exist		No exist	2.8
Fruit and vegetable intake, %											
<1 servings/day	75.5	68.8	68.6	.28	71.9	67.4	56.7	65.5	.08	63.9	68.6
1-2.9 servings/day	20.5	27.0	25.7		23.8	29.0	36.0	25.0		30.9	26.7
≥3 servings/day	4.0	4.2	5.7		4.3	3.6	7.3	9.4		5.2	4.7
Physical activity, %											
<600 MET-m/week	34.5	34.9	28.6	.30	33.8	51.6	52.5	42.4	.86	51.3	41.0
600-2999 MET-m/week	51.2	50.3	61.9		52.2	36.9	37.0	45.5		37.5	46.2
≥3000 MET-m/week	14.3	14.8	9.5		14.0	11.5	10.5	12.1		11.2	12.8

Abbreviations: BMI, body mass index; DBP, diastolic blood pressure; FBG, fasting blood glucose; HbA1c, glycated hemoglobin; HDL, high-density lipoprotein; MET-m/week, metabolic equivalent minutes per week; SBP, systolic blood pressure; USD, United States dollar.

[a]Data are presented as means ± standard deviations or percentages for continuous or categorical variables, respectively, except specified notes.

[b]Based on analysis of variance and χ^2 test for continuous and categorical variables, respectively.

[c]Data are presented as medians (inter quartile ranges) and *P* values by Kruskal-Wallis test.

Table 2. Odds Ratios (95% Confidence Intervals) of Prediabetes and Diabetes With Non-Biochemical Factors.

	Men		Women	
	Prediabetes	Diabetes	Prediabetes	Diabetes
BMI, kg/m^2 [a]				
<25.0	Ref	Ref	Ref	Ref
25.0-29.9	2.60 (1.68-4.05)	3.05 (1.66-5.57)	2.91 (1.67-5.05)	3.84 (0.98-14.9)
≥30	7.32 (1.54-19.65)	6.34 (1.30-30.88)	1.95 (0.61-6.24)	11.55 (1.51-88.56)
P for trend	<.001	<.001	<.001	<.001
Waist circumference, cm[a]				
Men <94, women <80	Ref	Ref	Ref	Ref
Men ≥94, women ≥80	2.60 (1.70-4.00)	3.41 (1.89-6.11)	2.61 (1.5-4.54)	4.82 (0.56-41.24)
Waist-to-hip ratio[a]				
Men <0.90, women <0.85	Ref	Ref	Ref	Ref
Men ≥0.90, women ≥0.85	1.74 (1.19-2.55)	2.48 (1.32-4.69)	2.78 (1.66-4.67)	3.11 (0.77-12.56)
Hypertensive level[a,b]				
Normal	Ref	Ref	Ref	Ref
Prehypertension (120/80 to 139/89 mmHg)	1.51 (0.98-2.31)	1.24 (0.61-2.51)	1.19 (0.75-1.90)	1.87 (0.71-4.90)
Hypertension (≥140/90 mmHg or on medication)	1.42 (0.84-2.43)	1.72 (0.79-3.71)	2.11 (1.16-3.82)	3.29 (1.11-9.78)
P for trend	.13	.09	.02	.04
Smoking status[a,b]				
Nonsmoker	Ref	Ref	—	—
Past smoker	0.83 (0.34-1.91)	1.45 (0.53-3.94)	—	—
Current smoker	2.76 (0.81-9.37)	2.21 (0.43-11.45)	—	—
Alcohol drinking, standard drinks/day[a,b]				
<1	Ref	Ref	—	—
2-2.9	1.08 (0.7-1.67)	0.79 (0.41-1.56)	—	—
≥3	1.70 (0.63-4.62)	1.67 (0.41-6.75)	—	—
P for trend	.44	.91	—	—
Fruit and vegetable intake, servings/day[a,b]				
<1	Ref	Ref	Ref	Ref
1-2.9	1.54 (0.99-2.37)	0.88 (0.45-1.73)	1.54 (0.98-2.41)	1.07 (0.42-2.77)
≥3	1.33 (0.50-3.48)	1.16 (0.27-4.89)	3.28 (1.24-8.60)	5.01 (1.04-24.21)
P for trend	.95	.98	.01	.21
Physical activity, MET-m/week[a,b]				
≥3000	Ref	Ref	Ref	Ref
600-2999	0.69 (0.39-1.23)	1.72 (0.65-4.60)	1.27 (0.59-2.73)	1.28 (0.22-5.03)
<600	0.77 (0.42-1.40)	1.07 (0.38-3.04)	1.06 (0.49-2.26)	0.52 (0.13-2.16)
P for trend	.60	.66	.75	.13
Educational level[a,b]				
Primary school or lower	Ref	Ref	Ref	Ref
Secondary school	0.87 (0.39-1.93)	0.51 (0.11-2.35)	1.48 (0.51-4.28)	3.99 (0.74-21.62)
College or higher	1.02 (0.52-1.99)	0.80 (0.25-2.60)	1.28 (0.55-2.99)	1.53 (0.33-7.20)
P for trend	.64	.77	.65	.91
Annual income, USD/adult[a,b]				
<500	Ref	Ref	Ref	Ref
500-1000	1.12 (0.62-2.01)	1.70 (0.67-4.32)	0.89 (0.51-1.58)	0.77 (0.23-2.54)
1001-1500	1.61 (0.85-3.07)	1.85 (0.67-5.15)	0.99 (0.51-1.92)	0.97 (0.23-4.10)
>1500	1.35 (0.72-2.50)	1.81 (0.65-5.05)	0.98 (0.51-1.90)	2.90 (0.79-10.59)
P for trend	.92	.30	.96	.13
Religious fasting[a,b]				
Yes	Ref	Ref	Ref	Ref
No	1.29 (0.87-1.89)	1.88 (1.07-1.15)	1.11 (0.70-1.77)	1.04 (0.39-2.80)

Abbreviations: BMI, body mass index; FBG, fasting blood glucose; HbA1c, glycated hemoglobin; MET-m/week, metabolic equivalent minutes per week; ref, reference; USD, United States dollar.

[a]Adjusted for age, education level, wealth, religious fasting, smoking (men only), alcohol drinking (men only), fruit and vegetable intake, physical activity, and hypertensive level.

[b]Additionally adjusted for BMI.

Table 3. Odds Ratios (95% Confidence Intervals) of Prediabetes and Diabetes With Lipids[a].

	Men						Women					
	Prediabetes			Diabetes			Prediabetes			Diabetes		
	Model 1[b]	Model 2[c]	Model 3[d]	Model 1[b]	Model 2[c]	Model 3[d]	Model 1[b]	Model 2[c]	Model 3[d]	Model 1[b]	Model 2[c]	Model 3[d]
Triglycerides	1.49 (1.30-1.72)	1.44 (1.21-1.71)	1.33 (1.11-1.58)	1.85 (1.48-2.31)	1.69 (1.29-2.22)	1.61 (1.22-2.13)	1.09 (0.92-1.29)	1.09 (0.91-1.31)	1.08 (0.90-1.30)	1.45 (1.02-2.26)	1.45 (0.99-2.14)	1.44 (0.97-2.13)
Total cholesterol	1.48 (1.28-1.70)	1.38 (1.16-1.64)	1.28 (1.07-1.53)	1.86 (1.49-2.33)	1.77 (1.35-2.32)	1.64 (1.25-2.16)	1.39 (1.15-1.67)	1.40 (1.16-1.70)	1.34 (1.11-1.64)	2.47 (1.59-3.85)	2.65 (1.62-4.34)	2.50 (1.52-4.11)
HDL cholesterol	0.84 (0.73-0.96)	0.83 (0.71-0.97)	0.91 (0.77-1.09)	0.72 (0.59-0.89)	0.79 (0.62-1.01)	0.86 (0.67-1.11)	0.76 (0.63-0.92)	0.82 (0.68-1.00)	0.90 (0.74-1.11)	0.56 (0.38-0.82)	0.56 (0.37-0.85)	0.62 (0.41-1.00)
Non-HDL cholesterol	1.56 (1.35-1.81)	1.43 (1.20-1.72)	1.30 (1.08-1.56)	1.99 (1.56-2.50)	1.88 (1.43-2.48)	1.71 (1.29-2.26)	1.59 (1.31-1.95)	1.59 (1.29-1.97)	1.47 (1.19-1.82)	2.82 (1.71-4.65)	3.60 (1.95-6.63)	3.28 (1.77-6.10)

Abbreviations: BMI, body mass index; FBG, fasting blood glucose; HbA1c, glycated hemoglobin; HDL, high-density lipoprotein.
[a]Odds ratios are shown based on 1-quartile increase of triglycerides, total, HDL-, and non-HDL cholesterols.
[b]Model 1: adjusted for age.
[c]Model 2: adjusted for age, education level, annual income, religious fasting, smoking (men only), alcohol drinking (men only), fruit and vegetable intake, physical activity, and hypertensive level.
[d]Model 3: adjusted for BMI in addition to Model 2.

prediabetes and diabetes for the first time among the Ethiopian population.

The increased non-HDL cholesterol and total cholesterol were independently associated with increased probabilities of prediabetes and diabetes both in men and women. Raised total cholesterol was reported to be associated with raised blood glucose by the analysis of the nationwide survey in 2015 in Ethiopia,[9] but association with raised non-HDL cholesterol was not reported before in Ethiopia. Non-HDL cholesterol draws attention as a more reliable biomarker to predict risks of atherosclerosis and cardiovascular diseases than LDL cholesterol, which could be unreliable when the level of triglycerides is high unless it is measured directly.[16] Non-HDL cholesterol, simply calculated as total cholesterol minus HDL cholesterol, includes all atherogenic lipoprotein particles. Our study also indicated that the association between decreased HDL cholesterol and increased probability of prediabetes and diabetes was not independent of BMI in both men and women, suggesting HDL cholesterol might be a less reliable indicator than non-HDL cholesterol. Non-HDL cholesterol was previously reported to show a better performance for predicting diabetes than total, HDL, and LDL cholesterols in Canadian and southern Chinese populations,[21-23] and in women in an eastern Chinese population.[24] Our study added to the evidence that non-HDL cholesterol could be a better predictor of diabetes than total, HDL, and LDL cholesterols in the Ethiopian population.

Abdominal obesity was significantly associated with the increased probability of prediabetes and diabetes. We found that BMI increase was independently associated with both prediabetes and diabetes in Ethiopian adults, while increased waist circumference and waist-to-hip ratio were independently associated with prediabetes in both men and women, and with diabetes in man. The associations of increased BMI and waist-to-hip ratio with the increased risk for diabetes were reported in the African population including Ethiopia and Malawi,[9,12,25] while the association of increased waist circumference with diabetes was inconsistent.[10] It might be due to appropriate cutoff values of waist circumference for the Ethiopian population have not been determined yet.[26]

The increased triglycerides and observing religious fasting were independently associated with increased probability of prediabetes and diabetes only in men but not women. It might be in part due to the difference in lifestyle of men and women in Ethiopia, including social norms to make women consume less animal products.[27] The majority of the study subjects had very low fruit and vegetable intakes and infrequent animal products intakes; therefore, the percentage of carbohydrate intake in total energy intake was likely to be high, which might contribute to increasing the level of triglycerides particularly in women. In addition, women's dietary practices might not be much different in the fasting periods, when the observers refrain to take all kinds of animal foods. Further studies on social determinants and nutritional practices are required. Our findings suggested that different lifestyle modification approaches are required in men and women to prevent diabetes.

Evidence for the association between diabetes and hypertension was reported worldwide.[28] We found that the association of raised blood pressure with prediabetes and diabetes was stronger in women than in men. Women were reported to show more serious endothelial dysfunction and hypertension and higher risks of ischemic cardiac diseases than men during the progress of prediabetes.[29,30] Our findings were in line with these previous reports.

We found that women who had more fruit and vegetable intakes were likely to have prediabetes and diabetes. Considering the high price of fruit and vegetables in the local market, higher intakes of fruit and vegetables might imply a higher socioeconomic status, which was linked to a higher possibility of exposure to an unhealthy lifestyle.

Low income and low education levels were widely reported to be associated with increased prevalence of diabetes in developed countries such as the United States, Canada, the United Kingdom, and Germany.[31-34] However, the association between low socioeconomic status and diabetes was insignificant in our study. Since we targeted public employees, the socioeconomic status might not be much different among them. It might be also due to the overall low socioeconomic status of the Ethiopian population comparing with the American and European populations.

The strength of our study is that we used both FBG and HbA1c to define prediabetes and diabetes which enhanced the reliability and that we identified non-HDL cholesterol as a potential predictor of diabetes among the Ethiopian urban population. However, this study has several limitations. First, this is a cross-sectional study and hence no causation can be implied. This article describes only associations and further studies are needed to explore causality. Second, all of the participants are located in the northern Ethiopia highland area, which may not represent the nationwide situation. Third, our study period included both fasting and nonfasting days, thus observing religious fasting might not reflect the fasting practice on the day of the data collection. Fourth, information on the position or type of employment, which might be related to lifestyles, was not available in the data. However, variables of annual income and physical activity levels were included in the regression models instead to alleviate the shortage.

Conclusion

This is the first study that identified factors associated with prediabetes and diabetes defined by both FBG and HbA1c in Ethiopian adults. Non-HDL cholesterol was found to be a potential risk factor of prediabetes and diabetes for the first time. Gender difference in the association with triglycerides, hypertension, and religious fasting practice suggests that different approaches of lifestyle modification or medical intervention may be required for men and women to prevent

diabetes. Findings of the current study might possibly provide clues for developing strategies for diabetes prevention and control in Africa or other regions with similar social backgrounds under a rapid economic growth such as low- and middle-income countries in Asia.

Declaration of Conflicting Interests

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