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Research Article

Correlation of dyslipidemia and athrogenic index of plasma with anthropometric measurements and clinical variables among diabetic patients in Dessie Comprehensive Specialized Hospital, Ethiopia, 2021

Mekuriaw Wuhib[1], Belachew Tegegne[1]*, Leul Mekonnen[1], Zemen Mengesha[1], Mitaw Girma[1], Mamo Solomon[2] and Getachew Wuhib[3]

[1]Department of Nursing, School of Nursing and Midwifery, College of Medicine and Health Science, Wollo University, Dessie, Ethiopia

[2]Department of Nursing, College of Medicine and Health Science, Wolkitie University, Wolkitie, Ethiopia

[3]Department of Orthopedics and Traumatology, School of Medicine, College of Medicine and Health Science, University of Gondar, Gondar, Ethiopia

Abstract

Background: Control of increased athrogenic index of plasma and lipid parameters in the early stage of diabetes mellitus helps diabetic patients to improve their quality of life and treatment outcomes. Limited studies were conducted on the assessment of dyslipidemia and its correlation with clinical and anthropometric variables among diabetes patients but no study was conducted on the correlation of the athrogenic index of plasma with anthropometric measurements among diabetes patients in this study area. The objective of this study was to assess the correlation of dyslipidemia and athrogenic index of plasma with anthropometric measurements and clinical variables among diabetic patients in Dessie Compressive Specialized Hospital, Northeast Ethiopia.

Methods: Institution-based comparative cross-sectional study was conducted from August 2020 to June 2021. A total of 250 diabetic and healthy control respondents were included in the study with convenience sampling. Semi-structured questionnaire of a modified WHO stepwise Approach to Surveillance for chronic disease was used to collect data. Finally, descriptive statistics and correlation analysis were conducted to assess the correlation between variables. A *p* - value of less than 0.05 was declared as the level of significance.

Results: Athrogenic Index of Plasma, Triglyceride to High-density Lipoprotein Ratio, Very-Low-Density Lipoprotein, systolic blood pressure, diastolic blood pressure, triglyceride, waist circumference, WHtR and BMI were statistically significantly higher among Type 2 DM groups. There was a significant positive linear correlation between triglycerides and waist circumference, between TG/HDL and WHtR, and between cholesterol and WHtR, but a significant negative linear correlation between HDL and waist circumference among the Type 2 DM group. Systolic blood pressure and pulse showed a significant positive linear correlation with WC, BMI, and WHtR among diabetics groups only. Our study showed that the pattern of lipid abnormalities observed among DM patients was high AIP in 68%, moderate AIP in 16% and all four groups of hyperlipidemia were found in 9% of diabetic patients. All lipid profiles showed a significant very strong positive linear correlation with AIP, but DHL has a significant very strong negative linear correlation with AIP among Type 2 DM groups.

Conclusion: The proportions of high athrogenic index of plasma and lipid profile disorders were higher in DM patients compared to healthy controls. Dyslipidemia and a high athrogenic index of plasma had a considerable correlation with anthropometric measurements and clinical outcomes of Type 2 DM patients. DM patients who have a higher athrogenic index of plasma and higher lipid parameters should be strictly followed based on their anthropometric measurements.

More Information

***Address for Correspondence:**
Belachew Tegegne, BSc, MSc in Adult Health Nursing, Department of Nursing, School of Nursing and Midwifery, College of Medicine and Health Science, Wollo University, Dessie, Ethiopia, Email: beletegegne@gmail.com

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Keywords: Anthropometric measurements; Athrogenic index of plasma; Correlation; Diabetes mellitus; Dyslipidemia and Ethiopia

Acronyms and abbreviations: AIP: Athrogenic Index of Plasma; BMI: Body Mass Index; CI: Confidence Interval; CVD: Cardiovascular Disease; DM: Diabetes Mellitus; DCSH: Dessie Comprehensive Specialized Hospital; FPG: Fasting Plasma Glucose; HDL: High-Density Lipoprotein; LDL: Low-Density Lipoprotein; MetS: Metabolic Syndrome; TG/HDL-C: Triglyceride to High-Density Lipoprotein Ratio; VLDL: Very-Low-Density Lipoprotein; WHtR: Waist to Height Ratio; WC: Waist Circumference

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Introduction

Diabetes mellitus is a group of various metabolic disorders of carbohydrate, protein, and fat. Diabetes is associated with a broad range of clinical presentations, from being asymptomatic to ketoacidosis or coma which requires continuous treatment with multifactorial risk-reduction strategies beyond glycemic control. The disease occurs either due to decreased insulin secretion, insulin resistance, or both [1,2].

Among the body composition components, body fat is responsible for the increase in the prevalence of common chronic diseases like diabetes mellitus [3]. Lipids have a very crucial role both, in the prevention and/or the development of many diseases especially chronic non-communicable diseases like Type 2 DM [4]. Dyslipidemia comprises a triad of raised triglycerides (TG); reduced high-density lipoprotein (HDL) and excess of small, dense low-density lipoprotein (LDL) which is prevalent in diabetes mellitus because insulin resistance or deficiency affects key enzymes and pathways in lipid metabolism [5]. HDL-mediated reverse cholesterol transport and the anti-oxidative and endothelial-protective features of HDL are impaired in Type 2 diabetes mellitus [3].

Low HDL cholesterol concentration reflects a dysregulation of HDL metabolism [6]. Hyperlipidemia is one of the commonest complications of diabetes mellitus and it predisposes to premature atherosclerosis and macrovascular complications [7]. Abnormal lipid profiles like lower LDL levels, elevated low-density lipoprotein, DM, and dyslipidemia reduce the ability of an individual to regulate the level of blood glucose which results in a number of major and some other minor complications [8]. Dyslipidemia and T2DM co-morbidity is highly associated with macrovascular complications like coronary artery disease, myocardial infarction, stroke, congestive heart failure, and peripheral vascular disease or increased chance of microvascular complication like retinopathy, nephropathy, and neuropathy. The increased triglyceride and the glucose index are associated with an increased risk of incident hypertension [8,9].

Evident correlations were observed between anthropometric and clinical variables with lipid profiles. Waist-to-height (WHtR) ratio and waist circumference could be used as a simple and non-invasive method for the detection of dyslipidemia as an important risk factor for cardiovascular complications [10]. There was a statistically significant association of triglycerides and HDL-C with increasing age, female sex, obesity, physical inactivity, and poor glycemic control of diabetes [11]. The correlation of cholesterol with TG and LDL cholesterol was positive. However, HDL cholesterol showed a negative correlation with LDL cholesterol [3].

Atherogenic Index of Plasma (AIP) is based on two important parameters TG and HDLc, both of which are independent risk factors for coronary artery disease (CAD) [12]. Athrogenic index of plasma (AIP) may be an important tool for analyzing the association of TGs and HDL-C ratio which reflects the balance between risk and protective lipoprotein forces, and both TGs and HDL-C are widely measured and available [13]. Lipid profiles and lipid ratios like athrogenic index of plasma (AIP) are found to have a good implication prospect in daily practice to assess cardiovascular risk in Type 2 diabetes mellitus which were calculated from the routinely done lipid profile parameters, especially in centers where new tests are not possible due to cost factor [11]. The atherogenic index of Plasma can be used as a regular monitoring index of cardiovascular disease (CVD) in everyday practice, especially in persons with other cardiovascular risk factors [14]. High athrogenic index of plasma (AIP) is a surrogate of small size LDL and correlated with high blood pressure, high BMI index, and independent predictor of coronary heart disease (CHD). These relations are observed at much lower AIP in females [15]. A study from Saudi revealed that multiple anthropometric parameters are required to correlate lipid profile and atherogenic index of plasma rather than a single parameter in Type 2 diabetes mellitus [16]. The need and challenges of managing diabetic patients' blood sugar label and related complications, while providing monthly follow-up in clinical areas is still unsatisfactory. Because most diabetic patients are suffering from a lot of complications that increased morbidity and mortality from DM which might be related to inadequate utilization of subclinical biochemical warnings like lipid level and atherogenic index of plasma. Limited studies were conducted on the assessment of dyslipidemia and its correlation with clinical and anthropometric variables among diabetes patients but no study was conducted on the correlation of the athrogenic index of plasma with anthropometric measurements among diabetes patients in Ethiopia. Therefore objective of this study was to assess correlation of dyslipidemia and athrogenic index of plasma with anthropometric measurements and clinical variables among diabetic patients.

Methods and materials

Study area, period and design

The study was conducted in Northeast Ethiopia, Dessie comprehensive specialized hospital in Dessie city. Dessie is the capital city of the South Wollo zone and has 16 Kebeles. It is around 401 Km from Addis Ababa, the capital of Ethiopia. Dessie comprehensive specialized hospital (DCSH) has 630 staff and among these are 75 senior doctors, 60 general physicians, 241 nurses, and 150 other health professionals. The hospital is serving around 7 million people with 240 beds capacity and giving services such as surgery, maternal and child health, emergency service, outpatient service, and inpatient service. DM clinic is one of the outpatient services

which are giving follow-up services for 1600 registered patients. This study was conducted from August 2020– June 2021. An institution-based unmatched comparative cross-sectional study was conducted.

Sample size, study subjects and sampling procedure

The Source populations for cases were all diabetic patients in the DCSH chronic diabetic follow-up clinic and the source populations for controls were all healthy subjects in the hospital. The study population for cases was all diabetic patients in the chronic follow-up clinic of DCSH (Dessie comprehensive specialized hospital) that comes during the data collection period. Similarly, the study population for controls was all healthy subjects in the hospital that comes during the data collection period. Inclusion criteria for cases were all diabetic patients aged 18 years and above who are currently attending their follow-up in DCSH diabetic clinic. Inclusion criteria for controls were all staff or patient attendants aged 18 years and above who are relatively healthy before data collection was included in the study. Exclusion criteria for cases and controls were: pregnant women, smokers, alcoholics, hypertensives, and antihypertensive treatment, and statin user was excluded from the study.

Two population mean formulas were used to calculate the sample size using open Epi, version 3, open-source calculator by considering the following assumptions: 95% confidence interval (two-sided), 80% power and the ratio of cases to controls group is 1:1. Taking the mean and standard deviation (SD) of HDL for T2DM (113.1 ± 43.2) and control group (100.1 ± 36.4) from a study conducted in Gondar [15], the sample size was determined to be 148 for each group and the total of 296. There were 1600 registered diabetic patients that follow their regular treatment in the DRH DM clinic chronic follow-up unit. As the participants come randomly to visit the follow-up clinic, for cases and control convenience sampling technique was employed at the time of participant selection.

Data collection tools and procedures

A structured questionnaire adapted from the WHO stepwise Approach to Surveillance for chronic disease was used after some amendments [17]. The questionnaire also included height, weight, waist circumference, blood pressure, fasting blood sugar level, lipid profile, and pulse rate. After getting written consent from the participants' data was collected by 6 BSc nurses and 3 BSc laboratory technologist trained for two days and who has experience in data collection. The responsibility of data collectors was filling out the structured questionnaire and taking different biological measurements. The consistency and completeness of data were checked by supervisors on daily basis.

Blood pressure was measured with a digital BP (Blood pressure) measuring instrument model Omron Hem-7121 made in China. Three intermittent blood pressure readings were taken after 5 minutes of rest, with the BP machine cuff placed mid-arm and an average of the readings was used for the study. When measuring height and weight, the subject made barefoot and take off any coat or jacket, wearing only lightweight clothes.

The Body-mass index (BMI) was calculated by divided weight (kg) by height (in meters) squared. Venous blood was drawn after 8 or more hours of fasting. Waist circumference (WC) was determined by using a non-extensible/non-stretchable tape measure that was placed around in the mid-axillary midway between the last rib and superior iliac crest then the recording was taken at on point of normal expiration. The fasting blood glucose and other chemistry tests were measured using the chemistry machine model Dirrul CST-240 made in China. Serum total cholesterol and triglyceride were determined by enzymatic estimation. LDL-c and Very low-density lipoprotein were determined using Friedewald's and related formulas as follows: LDL-C (mg/dl) = Non-HDLC - TG/5 [18], VLDL = TG ÷ 5 [19]. The cut-off values for dyslipidemia were according to the national cholesterol education program adult treatment panel III benchmarks [20]. Study dependent variables were dyslipidemia and AIP but independent variables include socio-demographic characteristics like age, sex, anthropometric variables like height, weight, waist circumference, waist to height ratio, and clinical variables like Fasting blood sugar, pulse rate, diastolic BP, systolic BP, duration with DM.

Operational definitions and definition of terms

The abnormal lipid profile was defined as TC ≥ 200 mg/dl, HDL-c < 40 mg/dl, LDL-c ≥ 130 mg/dl, and TAG ≥ 150 mg/dl [21]. The Athrogenic index of plasma (AIP) is a logarithmically transformed ratio of TG to HDL with < 0.1 low risks, 0.11 - 0.24 medium risk and 0.25 and above high risk [22]. The patient was categorized as diabetic if fasting plasma glucose (FPG) ≥126 mg/dl (≥7.0 mmol/l) or with a previous clinical diagnosis [23,24]. The patient was categorized as Overweight if their body mass index is between 25.0 and 29.9 kg/m [24]. The patient was categorized as Obese if body mass index is greater than or equal to 30.0 kg/m^2 or more [24]. A waist circumference of up to 94 cm for males and up to 80 cm for females was an acceptable range. Waist circumference > 94 for males and > 80 cm for females was an increased risk [24]. The patient was categorized as having a normal waist to height ratio if waist circumference (cm)/height (cm) was less than 0.5 and the Patient was categorized as waist to height ratio above normal if it is 0.5 and above [25].

Data quality management

During the study time, 6 data collectors and 3 supervisors were recruited. The training was given to them for two days on the objectives, relevance, and confidentiality of the study, respondent's rights, and data collection process. The

questionnaire was pre-tested on 5% of the sample size other than the study area. At the end of the day, filled questionnaires were checked for completeness and consistency of information by the supervisor and principal investigator, and errors were manually edited. Any uncertainty and other problems are well addressed by the data collectors' supervisors and the principal investigator. Interviewed patients' question chart was given a unique identification number to revisit in case of incomplete and inconsistent responses.

Data analysis procedures

Data were coded and entered into the computer using Epi data manager version 4.4.1. Then the data was exported to the Statistical Package for the Social Science (SPSS) version 25 for further analysis and the normality of the data was tested. Data were reported as mean and SD (standard deviation) for continuous variables, and percentages for categorical variables. A variable was compared using an independent sample t-test after checking for normal distribution. The strength of association between the pairs of variables was assessed by Pearson's correlation coefficient for those data that satisfy the Pearson correlation assumption and Spearman's rank correlation coefficient for those data that do not satisfy the pearson correlation assumption including ordinal variables. A variable with a *p* - value of less than 0.05 was considered statistically significant. Finally, the results were summarized and presented by using texts, tables and frequencies.

Results

Socio-demographic characteristics of respondents

Out of the total respondents, half (50%) were diabetics and the rest were nondiabetics. The age of the respondents ranges from 34-90 years. The mean (± SD) age of the respondents was found to be 53 (± 12.099) years. Among cases almost half (52%) were males and the rest were females. Among the control groups, 67 (53.6%) were males and 58 (46.4%) were females. When we compare baseline characteristics of our study group variables like AIP, TG/ HDL, VLDL, systolic blood pressure, diastolic blood pressure, total cholesterol, triglyceride, HDL, LDL, BMI, and age were higher among diabetic groups compared to non-diabetic groups. But only AIP, TG/HDL, VLDL, systolic blood pressure, diastolic blood pressure, triglyceride, and BMI have a statistically significant difference between the two groups. On the other hand, the mean pulse is higher among control groups but not statistically significant compared to case groups (Table 1).

The magnitude of high athrogenic index of plasma and dyslipidemia among DM and control respondents

Our study showed that the pattern of lipid abnormalities observed among DM patients was high AIP in 68%, moderate AIP in 16%, high triglyceride in 33.6% of patients, high LDL in 39.2%, and low HDL in 37.6%, high cholesterol in 26.4%. And all four groups of hyperlipidemia were found in 9% of diabetic patients. On the other hand, the pattern of lipid abnormalities observed among the control groups was high AIP in 8%, moderate AIP in 56%, high triglyceride in 19.8% of patients, high LDL in 20% and low HDL in 8%, and high cholesterol in 9.6%. The study revealed that this AIP and dyslipidemia magnitude difference was statistically significant (Table 2).

Table 1: Anthropometric measurements, lipid profiles, and clinical characteristics of T2DM and healthy controls at Dessie comprehensive specialized Hospital, Northeast, Ethiopia, 2021.

Variable	Diabetics		Control		*p* - value
	Mean	Std. Deviation	Mean	Std. Deviation	
AIP	0.24	0.2	0.14	0.1	0.008
TG/ HDL	4.08	2.5	3.2	1.9	0.01
Pulse	86.57	11.98	87.77	12.60	0.3
SBP	125.21	18.33	120.12	16.57	0.01
DBP	88.13	67.34	78.62	9.03	0.03
Total cholesterol	178.75	46.68	163.01	37.79	0.13
Triglyceride	172.49	91.66	127.66	52.97	0.00
HDL	47.59	20.91	46.96	15.77	0.58
LDL	119.65	37.32	105.25	38.96	0.17
VLDL	34.49	13.33	25.53	10.59	0.000
BMI	27.0559	16.53	23.12	4.44	0.00
Age	54.98	15.36	52.79	13.82	0.04
Creatinine	1.11	0.86	0.71	0.85	0.05
Duration with DM	4.21	2.5			
Fasting blood glucose	190.00	95.72	108.67	32.64	0.000
Waist circumference	93.03	13.48	87.09	25.9	0.04
WHtR	.63	0.39	.53	0.08	0.000

Athrogenic Index of Plasma, BMI: Body Mass Index; WHtR: Waist to Hip Ratio; HDL: High-Density Lipoprotein; LDL: Low-Density Lipoprotein; T2DM: Type II Diabetes Mellitus; TG/HDL-C: Triglyceride to High-density Lipoprotein Ratio; VLDL: Very-Low-Density Lipoprotein; ** and *: Comparison is significant at 0.01 and 0.05 levels (2-tailed) respectively.

Correlations between lipid profiles and AIP with anthropometric measurements

AIP and TG/ HDL showed a significant weak positive linear correlation with WHtR among the Type 2 DM group but not in the control group. There was a significant weak positive linear correlation between total cholesterol and WHtR among the Type 2 DM group but not in the control group. There was a significant positive linear correlation between triglycerides and waist circumference among the Type 2 DM group but not in the control group. There was a significant negative linear correlation between HDL and waist circumference among the Type 2 DM group only. Our study showed that other anthropometric measures have no linear correlation with triglycerides in both groups (Table 3).

Correlations of athrogenic index of plasma and lipid profiles with clinical outcomes of T2DM patients

Athrogenic index of plasma showed a significant weak positive linear correlation with fasting blood glucose among the Type 2 DM group but not in the control group. AIP and TG/HDL showed a significant weak positive linear correlation with systolic blood pressure among the Type 2 DM group but not in the control group. Similarly, low-density lipoprotein

Table 2: Magnitude of high Athrogenic index of plasma and dyslipidemia among DM and control respondents at Dessie comprehensive Specialized Hospital, Northeast, Ethiopia, 2021.

Variable	Category	Diabetics		Control		p -value
		Frequency	Percent	Frequency	Percent	
AIP	Below 0.1(low risk)	20	16%	45	36%	0.05
	0.1 and above (moderate/high risk)	105	84%	80	64%	
Total cholesterol	200 mg/dl and below	92	73.6%	112	90.4%	0.007
	≥ 200 mg/dl	33	26.4%	13	9.6 %	
Triglyceride	Below 150 mg/dl	83	66.4%	99	79.2%	0.000
	≥ 150 mg/dl	42	33.6%	26	19.8 %	
HDL	40 mg/dl and above	78	62.4%	115	92%	0.01
	< 40 mg/dl	47	37.6%	10	8%	
LDL	Below 130 mg/dl,	76	60.8%	100	80%	0.024
	≥ 130 mg/dl,	49	39.2%	25	20%	

Note: AIP: Athrogenic Index of Plasma; HDL: High-Density Lipoprotein; LDL: Low-Density Lipoprotein; ** and *: Comparison is significant at 0.01 and 0.05 levels (2-tailed) respectively.

Table 3: Pearson's correlations(r) between lipid profiles with BMI, WC, and WHR among T2DM and healthy controls at Dessie comprehensive specialized Hospital, Northeast, Ethiopia, 2021

Type 2 DM group (N = 125)				Control group (N = 125)		
Variables	BMI r(p)	WHR r(p)	Waist circumference r(p)	WHR r(p)	Waist Circumference r(p)	BMI r(p)
AIP	0.12(.15)	0.26(0.02)	0.05(.57)	0.08(0.6)	0.02(.89)	0.12(0.07)
TG/ HDL	0.13(0.14)	0.285*(0.01)	0.003(.97)	0.09(.62)	0.04(0.82)	0.2(0.92)
Total cholesterol	0.09(0.28)	0.25*(.03)	0.29(.02)	0.05(0.17)	0.16(0.072)	0.09(.28)
Triglyceride	0.09(.30)	.166(.06)	0.27*(.02)	0.03(0.86)	0.17(.361)	0.09(0.30)
HDL	-0.06(0.44)	-0.02 (0.77)	-0.33(0.04) *	-0.02(.77)	-0.03(0.65)	-0.06(0.44)
LDL	0.003(0.97)	0.078(0.38)	0.071(.43)	0.005(0.97)	0.07(0.42)	0.043(0.82)
VLDL	.09(0.30)	.16(.06)	0.05(0.53)	0.03(0.86)	0.20(0.26)	0.30(0.09)

Note: AIP: Athrogenic Index of Plasma; BMI: Body Mass Index; WHtR: Waist to Hip Ratio; HDL: High-Density Lipoprotein; LDL: Low-Density Lipoprotein; TG: Triglyceride; TC: Total Cholesterol; TG/HDL-C: Triglyceride to High-Density Lipoprotein Ratio; VLDL: Very-Low-Density Lipoprotein; *: Correlation is significant at 0.05 levels (2-tailed)

Table 4: Pearson's correlations(r) between AIP and lipid profiles with clinical variables among T2DM and healthy controls at Dessie comprehensive Specialized Hospital 2021.

Variables	Diabetics Group (*N* = 125)				Control group (*N* = 125)			
	Fasting Blood Glucose	Pulse	Systolic Blood Pressure	Diastolic Blood Pressure	Fasting Blood Glucose	Pulse	Systolic Blood Pressure	Diastolic Blood Pressure
AIP r(p)	0.25*(0.03)	0.14(0.11)	0.36**(0.00)	0.10(0.15)	0.10(0.25)	-.012(.933)	0.17(0.22)	0.19(0.16)
TG/HDL r(p)	0.12(0.12)	0.17(0.05)	0.28*(0.01)	0.023(0.79)	0.04(0.77)	.052(.716)	0.14(0.30)	0.08(0.55)
TC r(p)	0.06(0.47)	0.02(0.77)	0.06(0.45)	0.04(0.65)	0.15(0.28)	.14(0.10)	0.120(.17)	0.22*(0.01)
TG r(p)	0.112(0.20)	0.12(0.16)	0.15(0.19)	0.05(0.51)	0.049(0.72)	.03(0.70)	0.07(0.43)	0.1700(.05)
HDL r(p)	0.08(0.31)	-0.09(0.8)	-0.07(0.40)	0.06(0.46)	0.049(0.75)	0.20(0.14)	-0.18(0.19)	0.06(0.66)
LDL r(p)	0.004(0.96)	0.08(.33)	0.14(0.1)	0.28*(0.04)	0.22(0.16)	0.08(0.55)	0.12(0.41)	0.20(0.13)
VLDL r(p)	0.11(0.20)	0.12(.157)	0.114(0.19)	0.057(0.51)	0.049(.72)	0.03(0.70)	0.07(0.43)	0.17(0.05)

Note: AIP: Athrogenic Index of Plasma; HDL: High-Density Lipoprotein; LDL: Low-Density Lipoprotein; TG: Triglyceride; TC: Total Cholesterol; TG/HDL-C: Triglyceride to High-density Lipoprotein Ratio; VLDL: Very-Low-Density Lipoprotein; ** and *: Correlation is significant at 0.01 and 0.05 levels (2-tailed) respectively.

showed a significant weak positive linear correlation with diastolic blood pressure among the Type 2 DM group only (Table 4).

Correlations between anthropometric measurements and clinical outcome

Pulse showed a significant moderate positive linear correlation with WC, BMI, and WHtR among diabetics groups but a significant weak positive linear correlation with WC, BMI, and WHtR among non-diabetics. Similarly, systolic blood pressure showed a significant strong positive linear correlation with WC, BMI and WHtR among diabetics groups only. Diastolic blood pressure had no correlation with the three anthropometric measurements in both groups (Table 5).

Correlations between AIP and lipid profiles

All lipid profiles showed a significant very strong positive linear correlation with AIP, but DHL has a significant very strong negative linear correlation with AIP among Type 2 DM groups. Similarly triglyceride, VLDL showed a significant weak positive linear correlation with AIP. Like Type 2 DM groups the correlation between HDL and AIP is inverse relation but weaker among control groups (Table 6).

Table 5: Pearson's correlations (r) between anthropometric measurements and clinical variables among T2DM and healthy controls at Dessie comprehensive Specialized Hospital 2021.

Variables	Diabetics Group			Control group		
	WC	WHR	BMI	WC	WHtR	BMI
	r(p)	r(p)	r(p)	r(p)	r(p)	r(p)
Fasting Blood Glucose	0.31* (0.04)	0.03(.56)	0.13(0.96)	0.1(0.9)	0.14(0.8)	.11(0.98)
Pulse	0.38**(.000)	0.48**(.004)	0.51**(.002	0.34*(.05)	0.32**(.000)	0.30**(.000)
Systolic Blood pressure	0.56**(.000)	0.53**(.000)	0.45**(.000)	0.16(.32)	0.17(.28)	0.15(.36)
Diastolic Blood pressure	0.113(.08)	0.10(.09)	0.06(.32)	0.13(.07)	0.14(.06)	0.06(.14)

Note: BMI: Body Mass Index; WHtR: Waist to Height Ratio; **, and *: Correlation is significant at 0.01 level and 0.05 level (2-tailed) respectively

Table 6: Pearson's correlations(r) between AIP and lipid profiles among T2DM and healthy controls at Dessie comprehensive Specialized Hospital 2021.

Variable	AIP	
	Type II DM	Controls
Total cholesterol r(p)	0.43**(0.000)	0.02(0.88)
Triglyceride r(p)	0.75**(0.000)	0.25*(0.01)
HDL r(p)	-0.73**(0.000)	-0.23*(0.02)
LDL r(p)	0.28*(0.01)	0.05(0.68)
VLDL r(p)	0.75**(0.000)	0.25* (0.01)

Note: AIP: Athrogenic Index of Plasma; HDL: High-Density Lipoprotein; LDL: Low-Density Lipoprotein; TG: Triglyceride; TC: Total Cholesterol; TG/HDL-C: Triglyceride to High-density Lipoprotein Ratio; VLDL: Very-Low-Density Lipoprotein, ** and *: Correlation is significant at 0.01 and 0.05 levels (2-tailed) respectively.

Discussion

The proportions of AIP abnormalities and lipid profile disorders were higher in DM patients compared to apparently healthy controls similar study was reported in Ethiopia [26] and in Turkey [3]. Another study supported this idea by reporting that higher serum levels of fasting blood sugar, total cholesterol, low-density lipoprotein cholesterol, and triacylglycerol and lower levels of high-density lipoprotein cholesterol were reported in Type 2 diabetes mellitus patients [6,9,15,16,26].

There was a significant positive linear correlation between triglycerides and waist circumference, between TG/HDL and WHtR, and between cholesterol and WHtR, but a significant negative linear correlation between HDL and waist circumference among the Type 2 DM group. This finding is similar to low levels of HDL-C, high levels of TG and abnormal levels in BMI and waistline increase the risk of Type 2 DM in Chinese people [9]. The level of TC, LDL, and TG go high with an increase in BMI [27]. A study conducted in India showed that dyslipidemia and higher anthropometric indices were strongly correlated [28]. A statistically significant and positive correlation was found between BMI, WC, WHtR and TC [16]. A correlation was observed between anthropometric and clinical variables with lipid profile [10]. A weak, positive and significant correlation was obtained between BMI, WC, WHtR and TG while a weak, negative, and statistically significant correlation was obtained between BMI, WC, WHtR and HDL [16]. The justification for this finding is that metabolic syndromes, like higher LDL, cholesterol, and triglycerides have inverse relation with HDL. This is in line with the idea that LDL is the bad cholesterol and HDL is the good cholesterol. This finding is similar with finding in Turkey that reports the correlation of cholesterol with TG and LDL cholesterol was positive. However, HDL cholesterol showed a negative correlation with LDL cholesterol [3]. TG had a positive correlation with WC but HDL has a negative correlation with WC which is the reverse of TG. This finding is similar to findings like cholesterol esterification rate and HDL particle size are the points at which TGs interact with HDL-C. Low HDL-C and high TG concentrations induce both an increase in the proportion of small HDL particles and an increase in small, dense LDL particles [13]. This finding has clinical significance because Waist to height ratio (WHtR) and waist circumference (WC) could be used as simple and non-invasive methods for the detection of dyslipidemia as an important cardiovascular risk factor. It was suggested to use these indices as simple and inexpensive methods in clinical and epidemiological fields [10].

All lipid profiles showed a significant very strong linear correlation with AIP. AIP was also significantly correlated with mean systolic blood pressure; mean diastolic blood pressure, serum Triglycerides, total cholesterol, and fasting blood sugar. Another study reports that BMI and TG are positively correlated with AIP, while HDL is negatively correlated which supported our study findings [29]. The practical use of AIP can be used for assessing changes in the lipoprotein profile because AIP provides information about the atherogenicity of plasma and quantifies the response to therapeutic intervention. Many studies are suggesting that AIP reflects the delicate metabolic interactions within the whole lipoprotein complex [13]. In contrary to our finding fasting blood sugar was unrelated to lipid profile [28]. AIP and TG/HDL had shown a significant weak positive linear correlation with systolic blood pressure but low-density lipoprotein showed a significant weak positive linear correlation with diastolic blood pressure among Type 2 DM. AIP predicts high blood pressure, metabolic syndrome, and Coronary heart disease [30]. AIP was significantly correlated with waist circumference and BMI. In clinical settings, AIP can be used as a regular monitoring index of CVD in everyday practice, especially in persons with other cardiovascular risk factors [14].

High athrogenic index of plasma (AIP) is a surrogate of small size LDL and correlated with high blood pressure, high BMI index, and independent predictor of coronary heart disease (CHD). These relations are observed at much lower AIP in females. AIP has an association with trigerciceride and obesity and can predict high blood pressure, metabolic syndrome, and coronary heart disease [30]. Lipid profiles and lipid ratios like athrogenic index of plasma (AIP) are found to have a good implication prospect in daily practice to assess cardiovascular risk in Type 2 diabetes mellitus which were calculated from the routinely done lipid profile parameters, especially in centers where new tests are not possible due to cost factor [11]. A study from Saudi revealed that multiple anthropometric parameters are required to correlate lipid profile and atherogenic index of plasma rather than a single parameter in Type 2 diabetes mellitus [16].

Systolic blood pressure showed a significant strong positive linear correlation with WC, BMI, and WHTR among diabetics groups. Obesity parameters were higher among Type 2 diabetic patients than those without DM. Plasma total triglyceride and blood pressure were strongly and significantly high in patients with MetS as compared to those without DM. HDL and total peroxide were found at a significantly lower amount in patients with MetS as compared to healthy controls [9,31,32]. The mean values of anthropometric measurements and biochemical parameters were statically higher in the MS group [33]. It was found that waistline and BMI are key important variables relating to T2DM [9]. According to this study, Triacylglycerolemia was significantly associated with the risk of cardiovascular disease [15].

Athrogenic index of plasma showed a significant weak positive linear correlation with fasting blood glucose among the Type 2 DM group but other dyslipidemia parameters didn't show a correlation with fasting blood glucose. Contrary to our study fasting blood sugar, had been shown associated with dyslipidemia [34]. A clinical trial about the effect of pioglitazone on the atherogenic Index of plasma in patients with Type 2 Diabetes showed that the athrogenic index of plasma was inversely and significantly correlated with measures of insulin sensitivity, such as the homeostasis model assessment and quantitative insulin sensitivity check index. In contrast, AIP was not significantly correlated with HbA1C [35].

AIP and TG/HDL showed a significant weak positive linear correlation with systolic blood pressure among the Type 2 DM group but not in the control group. Similarly, low-density lipoprotein showed a significant weak positive linear correlation with diastolic blood pressure among the Type 2 DM group only. Prediction of cardiovascular disease (CVD) was mediated by high blood pressure due to high AIP among type II DM patients [30]. Evidence are supporting the increasing trend toward hypertension and cardiovascular disease more importantly due to dyslipidemia [36]. AIP could be recommended as a potential biomarker in the early diagnosis of CVD events in developing countries [37].

From the results discussed here, it is resolved that individuals with dyslipidemia are clearly more susceptible to a high athrogenic index of plasma. We have seen an important co-relation between anthropometric measurements and dyslipidemia which in turn can lead to a high athrogenic index of plasma. To conclude the proportions of high athrogenic index of plasma and lipid profile disorders were higher in DM patients compared to apparently healthy controls. Dyslipidemia and a high athrogenic index of plasma had a considerable correlation with anthropometric measurements and clinical outcomes of Type 2 DM patients. All lipid profiles showed a significant very strong positive linear correlation with AIP, but HDL has a significant very strong negative linear correlation with AIP among Type 2 DM groups. DM patients who have a higher athrogenic index of plasma and higher lipid parameters should be strictly followed based on their anthropometric measurements.

Conclusion

The proportions of high athrogenic index of plasma and lipid profile disorders were higher in DM patients compared to apparently healthy controls. Dyslipidemia and a high athrogenic index of plasma had a considerable correlation with anthropometric measurements and clinical outcomes of Type 2 DM patients. DM patients who have a higher athrogenic index of plasma and higher lipid parameters should be strictly followed based on their anthropometric measurements.

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Ethical consideration

Ethical clearance and the formal letter were obtained from the Wollo University College of medicine and health science ethical review board. The necessary permission letter was obtained from Dessie's comprehensive specialized hospital administrative office. Informed written consent was obtained from the study participants after explaining the purpose of the study. Confidentiality was assured for each participant all over the study. The study purpose, procedure, duration, possible risks, and benefits of the study were clearly explained to study participants by reading Amharic translated full participant information sheet. For this purpose, a consent form and participant information

sheet were attached as a cover page of each questionnaire stating the general objective of the study and issues of confidentiality which were discussed by the data collectors before proceeding with the data collection. Abnormal findings were linked to physicians for further investigation and treatment.

Author's contribution

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis, and interpretation, or in all these areas; took part in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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