talenta PUBLISHER

JETROMI
Journal of Endocrinology, Tropical Medicine, and Infectiouse Disease
Journal homepage: https://jetromi.usu.ac.id

THE ASSOCIATION BETWEEN LIPID PROFILES AND ATHEROGENIC INDEX WITH DIABETIC FOOT SEVERITY ACCORDING TO THE WAGNER-MEGGITT CLASSIFICATION

Almira Wilonna [*1], Muhammad Aron Pase [1], Dian Anindita Lubis [1]

[1]*Endocrine Division, Departement of Internal Medicine, Adam Malik Hospital / Faculty of Medicine, Universitas Sumatera Utara, Medan, Indonesia.*
[*]Corresponding Author: awilonna@gmail.com

ARTICLE INFO

Article history:
Received 04 October 2024
Revised 11 December 2024
Accepted 11 December 2024
Available online xxx

E-ISSN: 2686-0856
P-ISSN: 2686-0872

How to cite:
Almira Wilonna (2025). The Association Between Lipid Profiles And Atherogenic Index With Diabetic Foot Severity According To The Wagner-Meggitt Classification. Journal of Endocrinology, Tropical Medicine, an Infectiouse Disease Vol.07, No.01 (2025) 18-26. (make in IEEE style)

10.32734/jetromi.v7i1.18383

ABSTRACT

Introduction. Diabetic foot is a serious complication that leads to ulcers and amputations. Identifying risk factors, such as lipid profiles and atherogenic indices is crucial for the prevention and treatment of cardiovascular disease and peripheral arterial disease. This study aims to investigate the relationship between lipid profiles and atherogenic indices with the severity of diabetic foot, categorized by the Wagner-Meggitt classification, at Adam Malik Hospital.
Methods. This analytical observational study with a cross-sectional design was conducted at Adam Malik Hospital, involving 70 diabetic foot patients. Data were collected from medical records, focusing on lipid profiles. Atherogenic indices were calculated as ratios: TC/HDL, TG/HDL, and LDL/HDL. The severity of diabetic foot was measured using the Wagner-Meggitt classification. Statistical analysis included Chi-square and Spearman's rho tests.
Results. Of the 70 patients, most were aged 51-60 (41.4%), male (60%), and had normal BMI (57.1%). There was a significant correlation between diabetic foot severity and triglyceride levels (p=0.0002, r=0.358) as well as the TC/HDL ratio (p=0.02, r=-0.277). However, no significant relationships were found for total cholesterol (p=0.533), HDL (p=0.254), LDL (p=0.533), the TG/HDL ratio (p=0.158), or the LDL/HDL ratio (p=0.92).
Discussion: In this study, 60% of the participants were male. The findings align with previous studies, demonstrating a correlation between elevated triglycerides and lipid profile abnormalities with the severity of diabetic foot ulcers.
Conclusion. Triglycerides and the total cholesterol/HDL ratio are significantly associated with the severity of diabetic foot based on the Wagner-Meggitt classification.

Keyword: diabetic foot, lipid profile, atherogenic index, Wagner-Meggitt

ABSTRAK

Pendahuluan: *Kaki diabetik adalah komplikasi serius yang dapat menyebabkan ulserasi dan amputasi. Mengidentifikasi faktor risiko, seperti profil lipid dan indeks atherogenik, sangat penting untuk pencegahan dan pengobatan penyakit kardiovaskular dan penyakit arteri perifer. Penelitian ini bertujuan untuk menyelidiki hubungan antara profil lipid dan indeks atherogenik dengan keparahan kaki diabetik, yang dikategorikan berdasarkan klasifikasi Wagner-Meggitt, di Rumah Sakit Adam Malik.*
Metode*. Penelitian observasional analitik dengan desain potong lintang ini dilakukan di Rumah Sakit Adam Malik, melibatkan 70 pasien kaki diabetik. Data dikumpulkan dari catatan medis, dengan fokus pada profil lipid. Indeks atherogenik dihitung sebagai rasio: TC/HDL, TG/HDL, dan LDL/HDL. Keparahan kaki diabetik diukur menggunakan klasifikasi Wagner-Meggitt. Analisis statistik mencakup uji Chi-square dan uji rho Spearman.*
Hasil*. Dari 70 pasien, sebagian besar berusia 51-60 tahun (41,4%), laki-laki (60%), dan memiliki BMI normal (57,1%). Terdapat korelasi signifikan antara*

keparahan kaki diabetik dan kadar trigliserida (p=0,0002, r=0,358) serta rasio TC/HDL (p=0,02, r=-0,277). Namun, tidak ditemukan hubungan signifikan untuk kolesterol total (p=0,533), HDL (p=0,254), LDL (p=0,533), rasio TG/HDL (p=0,158), atau rasio LDL/HDL (p=0,92).
Diskusi: *Dalam penelitian ini, 60% peserta adalah laki-laki. Temuan ini sejalan dengan studi sebelumnya, yang menunjukkan korelasi antara peningkatan trigliserida dan abnormalitas profil lipid dengan keparahan ulser kaki diabetik.*
Kesimpulan: *Trigliserida dan rasio kolesterol total/HDL secara signifikan berhubungan dengan keparahan kaki diabetik berdasarkan klasifikasi Wagner-Meggitt.*

Keyword: *diabetic foot, lipid profile, atherogenic index, Wagner-Meggitt*

1. Introduction

Diabetes Mellitus (DM) is a group of metabolic diseases characterized by hyperglycemia due to defects in insulin secretion or action [1]. In 2021, it was estimated that 537 million people aged 20-79 had diabetes, with projections reaching 643 million by 2030. DM is a leading cause of death, with approximately 6.7 million deaths linked to diabetes and its complications [2]. Complications of DM include vascular disorders (both macrovascular and microvascular) and neuropathy [1]. Patients with DM are twice as likely to experience foot problems and peripheral artery disease (PAD). About 15-25% of those with DM will develop diabetic foot ulcers during their lifetime [3], [4]. Diabetic foot is often complicated as superficial wounds, ischemic wounds, infected wounds, and severely complicated ulcers lead to gangrene, abscess, necrotizing fascitis, or clinical signs of sepsis.

Diabetic foot ulcer severity was an independent predictor of healing, amputation, hospitalization, and survival [5]. Moreover, individuals living with diabetic foot ulcers have a lower quality of life and also carry significant stigma and greater morbidity. There are different procedures reported in the literature to avoid these complications, in particular, plantar foot ulcers and Charcot's foot as minimally invasive distal metatarsal diaphysis osteotomies and tibiotalocalcaneal arthrodesis using a retrograde intramedullary nail for chronic plantar DFU. Multiple risk factors contribute to the development of DFUs and other foot lesions such as gangrene and lower extremity infections: poor glycemic control; vascular disease; inadequate foot care; neuropathy and the subsequent loss of protective sensation; foot deformity; trauma; diabetes-related compromised immunity and infections [6]. Diabetic foot ulcers result from the interaction between neuropathy, ischemia, and infection due to prolonged hyperglycemia [7]. Poor glycemic control can lead to dyslipidemia, characterized by increased total cholesterol, triglycerides (TG), and low-density lipoprotein cholesterol (LDL-C), along with decreased high-density lipoprotein cholesterol (HDL-C). Dyslipidemia plays a significant role in atherosclerosis, which can exacerbate PAD and hinder wound healing [8], [9].

Studies indicate that HDL levels are lower in diabetic foot patients, with the TG/HDL ratio serving as an indicator of atherosclerosis [10]-[11]. Diabetic foot can be classified using several criteria, including the Wagner classification [12]. Complications from diabetic foot often result in amputations, with mortality rates after amputation reaching 56.6% within five years [13].

The increasing incidence of amputations and associated care costs highlights the need for early risk identification and management for diabetes patients [4]. While many studies link cardiovascular complications with DM and dyslipidemia, data on the role of lipid biomarkers and atherogenic indices in diabetic foot patients remain limited. This study aimed to validate the association between lipid profile and atherogenic indices with the severity of diabetic foot. Therefore, routine lipid profile testing for diabetic foot patients at Adam Malik Hospital is essential to prevent worsening conditions through risk factor management.

2. Research Methods

This research is an analytical observational study with a cross-sectional design, utilizing retrospective data collection from secondary medical records to assess the relationship between lipid profiles and atherogenic indices with the severity of diabetic foot based on the Wagner-Meggit criteria at Adam Malik Hospital. The study was conducted using inpatient medical record data after obtaining approval from the Health Research Ethics Committee of the Faculty of Medicine, Universitas Sumatra Utara. The research will be carried out within a specific timeframe, and data will be collected during the year 2023 until the required sample size is met.

Sampling will be conducted using a non-probability sampling technique, specifically consecutive sampling, through medical records. This technique involves collecting all samples that meet the previously established

research criteria. In this study, the Wagner-Meggit criteria will be used to measure the severity of diabetic foot, focusing on severity levels Wagner 3-5. This is because the number of samples with Wagner 1-2 criteria is too small. This condition arises as the research site is a tertiary referral hospital, where patients typically present with relatively high severity levels. Inclusion criteria are patients aged 18 years and older who are hospitalized patients with Wagner 3-5. Exclusion criteria are patients with statin therapy, fibrate therapy, chronic kidney disease, and damaged blood samples.

Secondary data collection was conducted in the form of samples from diabetic foot patients receiving treatment at Adam Malik Hospital through medical records. The data collected met the inclusion criteria and were not included in the exclusion criteria. Demographic and clinical information, as well as the severity of diabetic foot based on the Wagner-Meggit classification, operates on a six-grade scale, primarily assessing ulcer depth and tissue necrosis level. The data were obtained from the medical records. Information regarding lipid profiles and atherogenic indices (HDL, total cholesterol, LDL, TG, and the ratios TG/HDL, LDL/HDL, TC/HDL) was subsequently collected from the medical records. Data on lipid profile levels and demographic information of the subjects will be presented in the form of descriptive tables. The results of the descriptive analysis will be expressed as percentages for categorical scale data, while numerical scale data will be presented as mean values and standard deviations. Before conducting bivariate analysis, a normality test will be performed using the Kolmogorov-Smirnov test to determine whether the data distribution is normal.

Statistical Analysis

Bivariate analysis will be conducted to investigate the relationship between blood lipid profiles and atherogenic indices with the severity of diabetic foot, using the Chi-Square statistical test with a significance level indicated by p=0.05. If p⩾0.05, it indicates no relationship between the two variables, and vice versa. Furthermore, to determine the strength of the relationship between independent and dependent variables, the Spearman rank test will be used. All analyses will be conducted using SPSS (Statistical Product and Service Solutions) software.

3. Results

This study has been conducted at Adam Malik Hospital with the approval of the Research Ethics Committee of the Faculty of Medicine, Universitas Sumatera Utara. The research and data collection was carried out through the medical records of inpatient patients during the year 2023. The study was conducted using a cross-sectional method, and the design was based on consecutive sampling. A total of 70 samples were used in this study.

Based on Table 1 regarding the characteristics of the study samples below, out of a total of 70 samples, the average age of the study participants is 57 years, with the highest number found in the age range of 51–60 years, totaling 29 individuals (41.4%). There are 26 individuals (37.1%) aged over 60 years, 13 individuals (18.6%) in the age range of 41–50 years, and 2 individuals (2.9%) in the age range of 31–40 years.

Table 1. Research Data Characteristic

Parameter	Frequency (%)
Age (years)	
< 30	0 (0)
31 – 40	2 (2.9)
41 – 50	13 (18.6)
51 – 60	29 (41.4)
> 60	26 (37.1)
Sex	
Male	42 (60.0)
Female	28 (40.0)
Body mass index (kg/m^2)	
< 18.5	3 (4.3)
18.5 – 22.9	40 (57.1)
23.0 – 24.9	10 (14.3)
≥ 25	17 (24.3)
HbA1c	
Controlled	16 (22.9)
Uncontrolled	54 (77.1)

Based on Table 2, the lipid profile and atherogenic index characteristics of the study samples above, 67 individuals (95.7%) had normal cholesterol levels, while 3 individuals (4.3%) had high cholesterol levels. For triglyceride levels, 42 individuals (60.0%) had normal triglyceride levels, and 28 individuals (40.0%) had high triglyceride levels. Regarding HDL levels, 63 individuals (90.0%) had low HDL levels, while 7 individuals (10.0%) had high HDL levels. In terms of LDL levels, 67 individuals (95.7%) had normal LDL levels, and 3 individuals (4.3%) had high LDL levels. The ratio of Triglycerides/HDL (TG/HDL) showed high results in 68 individuals (97.1%) and low results in 2 individuals (2.9%). Based on the total cholesterol/HDL ratio, 41 individuals (58.6%) had high results, while 29 individuals (41.4%) had low results. In terms of the LDL/HDL ratio, 58 individuals (82.9%) had high results, while 12 individuals (17.1%) had low results. According to the severity of diabetic foot based on the Wagner-Meggit classification, the majority of patients fell into the Wagner 3 severity category, totaling 33 individuals (47.1%), followed by the Wagner 4 category with 24 individuals (34.3%) and Wagner 5 with 13 individuals (18.6%).

In this study, laboratory tests were conducted to measure total cholesterol, triglycerides, HDL, and LDL, which were categorized into two result groups: low and high. The data were then evaluated for their relationship with the severity of diabetic foot according to the Wagner-Meggit classification, which was divided into three result groups: Wagner 3, Wagner 4, and Wagner 5.

Table 2. The Relationship Between Lipid Profile and the Severity of Diabetic Foot

Parameter		Wagner Meggit Criteria			P- Value
		Wagner 3 (%)	Wagner 4 (%)	Wagner 5 (%)	
TC	Normal	32 (97)	23 (95.8)	12 (92.3)	0.781
	High	1(3)	1 (4.2)	1 (7.7)	
TG	Normal	26 (78.8)	11 (45.8)	5 (38.5)	0.009
	High	7 (21.2)	3 (12.5)	8 (61.5)	
HDL	Low	37 (100)	23 (100)	9 (90)	0.048
	High	0 (0)	0 (0)	1 (10)	
LDL	Normal	32 (97)	23 (95.8)	12 (92.3)	0.781
	High	1 (3)	1 (34.3)	1 (7.7)	
TG/HDL	Low	21 (93.9)	20 (83.3)	12 (92.3)	0.070
	High	12 (6.1)	4 (16.7)	1 (7.6)	
TC/HDL	Low	14 (42.4)	18 (75)	9 (69.2)	0.033
	High	19 (57.5)	6 (25)	4 (30.7)	
LDL/HDL	Low	27 (81.8)	15 (62.5)	10 (76.9)	0.021
	High	6 (18.1)	9 (37.5)	3 (23.07)	

Based on Table 3, the relationship between the LDL/HDL ratio and the severity of diabetic foot is as follows. In the examination results, individuals with a low LDL/HDL ratio were found, with 27 (81.8%) classified as Wagner 3, 15 (62.5%) classified as Wagner 4, and 10 (76.9%) classified as Wagner 5. Samples with a high LDL/HDL ratio included 6 (18.1%) individuals classified as Wagner 3, 9 (37.5%) classified as Wagner 4, and 3 (23.07%) classified as Wagner 5. Based on the results of the chi-square test and Spearman's correlation, a p-value of 0.92 ($p > 0.05$) was obtained. Therefore, it can be concluded that there is no significant relationship between the atherogenic index of LDL/HDL and the severity of diabetic foot according to the Wagner-Meggit classification, with a very weak positive correlation of $r = 0.012$.

Table 3. Correlation Between Lipid Profile and the Severity of Diabetic Foot

Variable	P value	R-value
TC-C	0.533	0.076
TG-C	0.002	0.358
HDL-C	0.254	0.138
LDL-C	0.533	0.076
TG/HDL	0.158	-0.17
TC/HDL	0.020	-0.277
LDL/HDL	0.920	0.012

4. Discussions

From the total of 70 research samples, the average age of the research samples is 57 ± 10 years. This is consistent with research conducted by Zubair et al., which states that in developing countries, the majority of patients with diabetes mellitus are in the age range of 45 to 64 years, resulting in an increased prevalence of diabetic foot occurring after the age of 40 years [14]. Another study by Manda et al. found that the average age of patients with diabetes mellitus is 54.7 ± 10.2 years, and the incidence of diabetic foot was found to be > 75% in the age group of 30-60 years, with the highest numbers in the 50-59 age group [15]. Research by Ikura et al. also yielded similar results, where the average age of patients with diabetic foot is 62 years. It can thus be stated that the occurrence of diabetic foot can happen in the 5th and 6th decades of life. This is due to the increased risk of developing diabetic foot as age increases, related to the longer duration of diabetes mellitus, the cumulative effects of hyperglycemia, and the higher prevalence of microvascular and macrovascular complications. Several previous studies have also shown that older age is one of the main factors related to the severity of diabetic foot [15], [16].

In terms of gender data, the majority of the samples were male, with 42 (60.0%) individuals and 28 (40.0%) individuals being female. According to research by Abdallah et al., it was found that males have a 1.4 times higher risk of developing dyslipidemia [23]. The results of this study are in line with research by Hamri et al., which indicated that high total cholesterol levels were found more in males than in females. This is because males tend to engage in outdoor activities more than females, which causes the plantar feet to experience more pressure and exposure to various risks [11].

The differences based on gender are influenced by underlying risk factors, access to care, screening, and treatment adherence. Adherence to therapeutic footwear usage is similar between males and females, but females tend to engage in self-care and foot care more frequently than males. Males with diabetes mellitus also have a higher prevalence of peripheral artery disease (PAD) and cardiovascular diseases, which is the primary reason for the majority of the differences in the risk of developing diabetic foot between the two genders [17], [18].

Based on BMI data, this study found an average BMI of 22.9 ± 2.8 kg/m². Based on research by AbdAllah et al., there is a significant relationship between the occurrence of dyslipidemia and BMI [19]. However, several other prospective studies state that BMI does not have a significant relationship with diabetic foot. A recent study indicated that the relationship between BMI and diabetic foot is J-shaped, with patients having a BMI <25 kg/m² and a BMI ⩾45 kg/m² showing a high correlation with the occurrence of diabetic foot. This study reported that 77.1% of patients with diabetic feet have uncontrolled HbA1c levels. This aligns with previous studies conducted by Silalahi in 2017 at Adam Malik Hospital, which reported a relationship between HbA1c and the occurrence of diabetic foot [20].

In this study, total cholesterol (TC) levels were examined and then categorized into two groups: normal and high. A test was then conducted to determine if there was a relationship between total cholesterol levels and the severity of diabetic foot. The bivariate test results between total cholesterol levels and the severity of diabetic foot in this study showed no significant relationship between the two with a p-value of 0.533. These results are not in line with research by Sinulingga et al., where a significant relationship was found between total cholesterol levels and the severity of diabetic foot. In that study, it was stated that statistically, high total cholesterol levels could reduce the risk of diabetic foot ulcers, which contradicts existing theory. The differences found in this study compared to previous research may be due to different sampling techniques, such as methods and examination tools. Additionally, individual characteristics such as age, gender, comorbidities, and medication history may also contribute to these differences. Theoretically, high total cholesterol can worsen the severity of diabetic foot due to its ability to disrupt blood flow, leading to hypoxia in surrounding cells and tissues. This is supported by the correlation value found in this study, which is r=0.076, indicating a very weak correlation between total cholesterol and the severity of diabetic foot. This is consistent with the theory that total cholesterol levels can affect the severity of diabetic foot. The higher a person's total cholesterol level, the worse their diabetic foot condition can become [10]. This study also examined triglyceride (TG) levels, which would later be tested for their relationship with the severity of diabetic foot. The bivariate test results in this study showed a significant relationship between triglyceride levels and the severity of diabetic foot with a p-value of 0.002. This is consistent with previous research conducted by Ario et al., which found a significant relationship between TG levels and the severity of diabetic foot with a p-value of 0.01 [21]. The findings of this study align with a meta-analysis conducted by Juan et al. on the relationship between lipid profiles and apolipoproteins with the risk of developing diabetic foot, which found that high TG levels are associated with a high risk of diabetic foot with a p-value <0.05 [22].

Triglycerides are known to be an important factor in the pathogenesis of diabetic neuropathy. Increased triglyceride levels are thought to contribute to nerve damage in patients with diabetic neuropathy and correlate with worsening neuropathic symptoms and structural nerve abnormalities. Hypertriglyceridemia has long been recognized as a marker of cardiovascular disease risk, where the accumulation of triglyceride-rich lipoproteins in plasma is directly atherogenic. Hypertriglyceridemia may also serve as a marker for other atherogenic

conditions such as insulin resistance, visceral adiposity, and hyperglycemia. In the correlation test conducted in this study, a correlation was found between triglycerides and the severity of diabetic foot, with a value of r=0.358 indicating a weak correlation between triglycerides and the severity of diabetic foot. This aligns with the theory that high triglyceride levels can influence the severity of diabetic foot [23].

The bivariate test results between LDL levels and the severity of diabetic foot in this study showed no significant relationship between the two with a p-value of 0.781. Similar results were found in research by Sinulingga et al., where LDL levels in patients with diabetic foot were also found to be lower than in patients without diabetic foot. This may occur because oxidized LDL levels are associated with a higher risk of atherosclerosis. A study in Turkey on atherosclerosis in diabetic foot stated that ox-LDL levels were found to be elevated even when LDL levels were <100 mg/dL. The increased ox-LDL levels may also elevate the risk of atherosclerosis [10]. The correlation test conducted in this study yielded r=0.076, which indicates a very weak correlation between LDL and the severity of diabetic foot. However, this result is consistent with the theory that high LDL can affect the severity of diabetic foot. High LDL can lead to atherosclerosis, which may trigger diabetic foot. If a patient's LDL levels increase, the severity of their condition is likely to worsen. The differences in the research results and the discrepancies with the hypothesis in this study may be attributed to the retrospective nature of this research through secondary data, resulting in limited control over confounding factors such as the dietary history of the patients and previous treatment history in other health facilities before coming to Adam Malik Hospital.

This study also examined the relationship between HDL levels and the severity of diabetic foot and found no significant relationship between the two with a p-value of 0.048. These results align with research conducted by Kartono et al., which states that there is a correlation between HDL and the severity of diabetic foot based on Wagner criteria, where it was found that lower HDL cholesterol levels were associated with higher severity of diabetic foot, albeit with a weak correlation [15]. The study by Ikura et al. also showed different results compared to this study, indicating a low correlation between HDL levels and diabetic foot severity with an increasing incidence of infections. Furthermore, this study produced a hypothesis evaluation suggesting that HDL is a predictor of amputation and wounds in patients with diabetic feet. HDL plays a role in reverse cholesterol transport (RCT) and directly influences cardiovascular and other metabolic processes. Low HDL levels in previous studies have been associated with impaired healing of diabetic foot wounds. Besides its antithrombotic effects, HDL also plays a role as an anti-inflammatory, and cytoprotective agent, promotes wound healing, and can prevent the worsening of the severity of diabetic foot according to the Wagner classification [15].

A recent study in Surabaya conducted by Abuajwa et al. in 2023 reported no definitive relationship between HDL levels in amputated and non-amputated diabetic foot patients; however, this study showed that lower HDL levels were found more frequently in amputated diabetic foot patients. From this study, a p-value of 0.254 and r=-0.138 was found, indicating no correlation between HDL levels and the severity of diabetic foot, with a negative correlation value. The negative correlation indicates that higher HDL levels can reduce the severity of diabetic foot. Conversely, lower HDL levels can worsen the diabetic foot condition [24]. This study also assesses the relationship between the atherogenic index of total cholesterol (TC)/HDL with the severity degree of diabetic foot. The results indicate a significant relationship between the two, with a p-value of 0.020. The findings of this study align with the research by Hamri et al., which found that the TC/HDL ratio is a precise marker for atherosclerosis. The optimal cut-off value is $\geqslant$ 4.0, with a sensitivity of 86.3%, a specificity of 71.4%, and a diagnostic accuracy of 0.836. In that study, a significant result was found between increased TC/HDL and patients with diabetic foot [11]. From the correlation test in this study, an r value of -0.277 was found, indicating a weak negative correlation between TC/HDL and the severity of diabetic foot. A negative correlation suggests that TC/HDL is inversely related to the severity of diabetic foot, meaning that when the TC/HDL ratio is low, the severity of diabetic foot will become worse. This contrasts with a study in Makassar that reported a high TC/HDL ratio correlating with the severity of diabetic foot. Additionally, that study reported that a high TC/HDL ratio tends to lead to worse clinical outcomes post-treatment compared to patients with a lower TC/HDL ratio. The difference in results in this study occurred due to the lack of a relationship between TC and the severity of diabetic foot. The majority of patients (95.7%) had normal TC values, which can affect the TC/HDL ratio. This may be due to the study method used, which was a cross-sectional technique, and lipid profiles were only taken at one time [25].

Furthermore, this study also investigates the relationship between the atherogenic index of triglycerides (TG)/HDL and the severity degree of diabetic foot. The results show no significant relationship between the two, with a p-value of 0.158. The findings of this study do not align with the research by Hamri et al., which found a significant relationship between increased TG/HDL in patients with diabetic foot, with an optimal cut-off value of $\geqslant$ 3.0. The sensitivity of the TG/HDL ratio was 64.1%, specificity 61.2%, and diagnostic accuracy of 0.740 [11]. This study also does not align with the study conducted by Ardelean et al., which stated that triglyceride levels along with HDL have been identified as risk factors for the development of diabetic foot. This could also be influenced by patient compliance with medication, which may result in high triglyceride or

HDL levels, thereby affecting the severity of diabetic foot [26]. The r value found in this study was r = -0.170. This result indicates an inverse correlation between TG/HDL and the severity of diabetic foot with a very weak correlation. The negative correlation value indicates that as the TG/HDL ratio decreases, the severity of diabetic foot in patients increases. This study does not align with research by Albert et al., which reported that a high TG/HDL ratio correlates with the severity of diabetic foot. Additionally, this study reported that a high TG/HDL ratio tends to lead to worse clinical outcomes post-treatment compared to patients with a lower TG/HDL ratio.32 The difference in results in this study may be due to about 68 (97.1%) of patients having a high TG/HDL ratio, with only 2 patients having a low TG/HDL ratio. This may explain why the TG/HDL ratio is statistically not related to the severity of diabetic foot. Furthermore, the degree of diabetic foot in this study was only investigated using Wagner-Meggit criteria of degrees 3, 4, and 5; different results might be obtained if patients with degrees 1 and 2 were included.

The relationship between the atherogenic index of LDL/HDL and the severity of diabetic foot in this study found no significant relationship between the two, with a p-value of 0.092. The r value found in this study was r = 0.012. This result shows a positive correlation between LDL/HDL and the severity of diabetic foot, with a weak correlation value. This study does not align with research by Hamri et al., which states that the LDL/HDL ratio is a sufficiently valid marker for atherosclerosis. The optimal cut-off value for this ratio is $\geqslant$ 2.5, with a sensitivity of 69.8%, specificity of 66.2%, and diagnostic accuracy of 0.772. The study also found significant results between high LDL/HDL levels in patients with diabetic foot [11]. A study in Surabaya reported that high LDL/HDL levels were found in non-amputated diabetic foot patients, which is indirectly related to the severity of diabetic foot. This is consistent with the theory that high LDL levels can lead to poor blood flow, potentially damaging tissues. Conversely, low HDL can contribute to the formation of atherosclerosis. The reasons for the differences in this study compared to other studies are also due to the lack of a relationship between LDL and the severity of diabetic foot. Furthermore, the majority of patients (95.7%) had normal LDL values, which can influence the LDL/HDL ratio. This may be due to the study method used, which was cross-sectional, where lipid profiles were only taken at one time [24].

The current study is the first research reporting the relationship between lipid profiles and atherogenic indices with the severity of diabetic foot at Adam Malik Hospital in Medan. This study also utilizes simple markers such as lipid profiles and atherogenic indices that can be used as markers for the severity of diabetic foot. The limitations of this study include a relatively small sample size of patients with Wagner-Meggit criteria of degrees 3 to 5. The limited and non-diverse sample is due to Adam Malik Hospital being a tertiary referral hospital where referred patients are those with Wagner-Meggit degrees above 3 with many complications, making it difficult to obtain samples with degrees 1 and 2. Additionally, this study lacked a control group and utilized a cross-sectional design, meaning that lipid profile and atherogenic index examinations were only conducted at one point in time.

5. Conclusions

The study found a significant relationship between triglyceride levels and the TC/HDL ratio with the severity of diabetic foot based on the Wagner-Meggit criteria. For future researchers, it is hoped that further studies can be conducted on this research topic using primary data, multi-center approaches, a larger sample size, and incorporating other factors that may be related to the severity of diabetic foot, such as the duration of diabetes mellitus treatment, smoking habits, and previous history of foot deformities.

Acknowledgments

The author would like to express gratitude to all patients, lecturers, and laboratory staff, who have helped in carrying out this research. In particular, thank you to the Faculty of Medicine Universitas Sumatera Utara.

Conflict of Interest

The authors declare no conflict of interest in this research.

References

[1] Indonesia PE. Pedoman Pengelolaan dan Pencegahan Diabetes Melitus Tipe 2 Dewasa di Indonesia 2021. Jakarta: Perkumpulan Endokrinologi Indonesia. 2021.

[2] Magliano D, Boyko EJ. IDF Diabetes Atlas. 10th ed. Brussels: International Diabetes Federation; 2021.

[3] Kartono, Tommy, et al. "Correlation of HDL cholesterol serum and Wagner's severity level of diabetic foot ulcers." Int J Res Med Sci 5 pp. 5129-34, 2017. doi: http://dx.doi.org/10.18203/2320-6012.ijrms20175431

[4] Lee, Jun Ho et al. "Risk factors affecting amputation in diabetic foot." Yeungnam University Journal of Medicine vol. 37, no. 4, pp 314-320. Oct. 2020, doi:10.12701/yujm.2020.00129

[5] Meloni, Marco, et al. "Validation of the Fast-Track Model: A Simple Tool to Assess the Severity of Diabetic Foot Ulcers." Journal of Clinical Medicine vol. 12, no.3, pp. 761, Jan. 2023, doi: 10.3390/jcm12030761

[6] Stancu, Bogdan et al. "Diabetic Foot Complications: A Retrospective Cohort Study." International Journal of Environmental Research and Public Health vol. 20, no.1, pp. 187. Dec. 2022, doi:10.3390/ijerph20010187

[7] Almobarak, Ahmed O., et al. "Prevalence of diabetic foot ulceration and associated risk factors: an old and still major public health problem in Khartoum, Sudan?." Annals of translational medicine vol. 5, no. 17, pp. 340–340, Sept. 2017. doi: 10.21037/atm.2017.07.01

[8] Lestari, Putri Hidayasyah Purnama, Nurahmi Nurahmi, Tenri Esa, and Liong Boy Kurniawan. "Analisis rasio profil lipid kolesterol total, High Density Lipoprotein (HDL), Low Density Lipoprotein (LDL), dan trigliserida pada pasien Diabetes Melitus Tipe 2 (DM-2) dengan dan tanpa komplikasi ulkus kaki diabetik." Intisari Sains Medis vol.11, no. 3, pp. 1333-1340, Dec. 2020. doi: 10.15562/ism.v11i3.764

[9] Vujčić, Sanja, Tatjana Stefanović, Aleksandra Zeljković, Marija Mihajlović, and Jelena Vekić. "Biomarkers of dyslipidemia in patients with diabetic foot." Arhiv za farmaciju vol. 72, no. 2, pp. 184-192, 2022. doi: 10.5937/arhfarm72-36296

[10] Schaper NC, van Netten JJ, Apelqvist J, Bus SA, Hinchliffe RJ, Lipsky BA. IWGDF guidelines on the prevention and management of diabetic foot disease. Maastricht: IWGDF. 2019.

[11] Babic, Nermina, Amina Valjevac, Asija Zaciragic, Nesina Avdagic, Sabina Zukic, and Sabaheta Hasic. "The triglyceride/HDL ratio and triglyceride glucose index as predictors of glycemic control in patients with diabetes mellitus type 2." Medical Archives vol. 73, no. 3, pp. 163, Jun 2019. doi:10.5455/medarh.2019.73.163-168

[12] Hamri, Walid Hassene, and Mustapha Diaf. "Lipoprotein ratios: A potential biomarker for clinical diagnosis of atherosclerosis in type 1 diabetic patients with foot ulceration." Cureus vol. 13, no. 3, March 2021. doi:10.7759/cureus.14064

[13] Rosedi, Anas, Suhaily Mohd Hairon, Noor Hashimah Abdullah, and Nor Azwany Yaacob. "Prognostic factor of lower limb amputation among diabetic foot ulcer patients in north-east peninsular Malaysia." International Journal of Environmental Research and Public Health vol. 19, no. 21, pp. 14212, Oct 2022. doi: 10.3390/ijerph192114212

[14] Noor, Saba, Mohammad Zubair, and Jamal Ahmad. "Diabetic foot ulcer a review on pathophysiology, classification, and microbial etiology." Diabetes & Metabolic Syndrome: Clinical Research & Reviews vol. 9, no. 3, pp. 192-199, Jul. 2015. doi: https://doi.org/10.1016/j.dsx.2015.04.007

[15] Manda, Venkatramana, Jayadevan Sreedharan, Jayakumary Muttappallymyalil, Rajdeep Das, and Emi Hisamatsu. "Foot ulcers and risk factors among diabetic patients visiting Surgery Department in a University Teaching Hospital in Ajman, UAE." International Journal of Medicine and Public Health vol. 2, no. 3, pp. 34-38, Jul. 2012.

[16] Ikura, Kazuki, Ko Hanai, Takamichi Shinjyo, and Yasuko Uchigata. "HDL cholesterol as a predictor for the incidence of lower extremity amputation and wound-related death in patients with diabetic foot ulcers." Atherosclerosis vol. 239, no. 2 pp. 465-469, Apr 2015. doi: https://doi.org/10.1016/j.atherosclerosis.2015.02.006

[17] Rosinha, Patrícia, Miguel Saraiva, Lia Ferreira, Susana Garrido, André Carvalho, Cláudia Freitas, Cláudia Amaral, Luís Costa, Luís Loureiro, and Rui Carvalho. "A retrospective cohort study on diabetic foot disease: ascertainment of ulcer locations by age group." Cureus vol. 14, no. 8, Aug. 2022. doi:10.7759/cureus.28189

[18] Tyagi, A., S. Lavanya, and G. Hari Prasad. "A clinical study of peripheral vascular disease due to atherosclerosis in diabetic foot infections." International Surgery Journal vol. 5, no. 3, pp. 931-936, Feb 2018. doi: https://doi.org/10.18203/2349-2902.isj20180806

[19] Yazdanpanah, Leila, Hajieh Shahbazian, Iraj Nazari, Hamid Reza Arti, Fatemeh Ahmadi, Seyed Ehsan Mohammadianinejad, Bahman Cheraghian, and Saeed Hesam. "Incidence and risk factors of diabetic foot ulcer: a population‐based diabetic foot cohort (ADFC study)−two‐year follow‐up study." International Journal of Endocrinology 2018, no. 1, pp. 7631659. doi: https://doi.org/10.1155/2018/7631659

[20] Callaghan, Brian C., Eva Feldman, Jennifer Liu, Kevin Kerber, Rodica Pop-Busui, Howard Moffet, and Andrew J. Karter. "Triglycerides and amputation risk in patients with diabetes: ten-year follow-up in the DISTANCE study." Diabetes care vol. 34, no. 3, pp. 635-640, Mar 2011. doi: https://doi.org/10.2337/dc10-0878

[21] Silalahi, Fernando. "Hubungan Glycosylated Hemoglobin (HbA1c) dengan Angka Kejadian Kaki Diabetik di RSUP H. Adam Malik." PhD diss., Universitas Sumatera Utara, 2017.

[22] Dayya, David, Owen J. O'Neill, Tania B. Huedo-Medina, Nusrat Habib, Joanna Moore, and Kartik Iyer. "Debridement of diabetic foot ulcers." Advances in wound care vol. 11, no. 12, pp. 666-686, Dec 2022. doi: https://doi.org/10.1089/wound.2021.0016

[23] Ulloque-Badaracco, Juan R., Melany D. Mosquera-Rojas, Enrique A. Hernandez-Bustamante, Esteban A. Alarcon-Braga, Ricardo R. Ulloque-Badaracco, Ali Al-Kassab-Cordova, Percy Herrera-Añazco, Vicente A. Benites-Zapata, and Adrian V. Hernandez. "Association between lipid profile and apolipoproteins with risk of diabetic foot ulcer: a systematic review and meta‐analysis." International Journal of Clinical Practice 2022, no. 1, pp. 1‐15, Aug. 2022. doi: https://doi.org/10.1155/2022/5450173

[24] Duell, P. Barton. "Triglyceride-rich lipoproteins and atherosclerotic cardiovascular disease risk." Journal of the American College of Cardiology vol. 81, no. 2, pp.153-155, Jan 2023.

[25] Abuajwa, Ahmed Eliaan Shaker, Hermina Novida, Heroe Soebroto, and Yan Efrata Sembiring. "The HDL Level in Diabetic Foot Ulcer Patients with and without Amputation at Dr. Seotomo General Academic Hospital Surabaya." Majalah Biomorfologi vol. 33, no. 1, 2023.

[26] Albert, Mulawardi, Adriani TC. “Correlation of lipid profile and lipoprotein ratio with severity of diabetic foot ulcers.” Ital J Vasc Endovasc Surg 2023, vol. 30, no.3, pp. 89–94, Sept. 2023. doi: 10.23736/S1824-4777.23.01594-2