ORIGINAL PAPERS

The relationship between anthropometry and ankle-brachial index with blood glucose level in patients with type 2 diabetes mellitus at the Community Health Center in Medan, Indonesia

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A – Study Design, B – Data Collection, C – Statistical Analysis, D – Data Interpretation, E – Manuscript Preparation, F – Literature Search, G – Funds Collection

Summary **Background.** Diabetes mellitus (DM) is a group of metabolic diseases with characteristics of hyperglycemia due to abnormalities of insulin secretion, impaired insulin function or both. Increased blood sugar levels in the body can cause the changes within the body, which then can be measured by using anthropometry as well as the measurement of vascularization changes to the periphery. **Objectives.** This study aimed to determine the relationship between anthropometry and ankle-brachial index (ABI) with blood glucose level (BGL) in patients with type 2 diabetes mellitus at Tuntungan Community Health Center in Medan. **Material and methods.** The study design was a cohort observational cross-sectional study. Research samples were patients with type 2 diabetes mellitus in Tuntungan Community Health Center determined by consecutive sampling; inclusion and exclusion criteria were also considered. Primary data was used as the data source for the study. Anthropometry and ankle-brachial index were directly measured from diabetic patients whereas ad random BGL was measured using a portable device. Data were analyzed using SPSS computer program. **Results.** Among 101 diabetic respondents, the results showed that 65 respondents (64.3%) had normal ad random blood glucose level while 36 respondents (35.6%) were hyperglycemic. Based on the results of chi-square, there was a relationship found between BMI, ABI, waist circumference, and BGL ($p = 0.001$; $p = 0.0001$; $p = 0.0001$). In contrast, no relationship was found between blood pressure, waist-hip ratio, upper arm circumference, and BGL ($p = 0.07$; $p = 0.37$; $p = 0.77$). **Conclusions.** The results showed that uncontrolled BGL very closely related to complications experienced by patients such as macro vascular complications.
Key words: anthropometry, ankle-brachial index, blood glucose level, type 2 diabetes mellitus.

Background

Diabetes mellitus is a group of metabolic disease characterized by hyperglycemia, which is caused by insulin secretion abnormalities, impaired functions of insulin, or both [1]. The classical symptoms of diabetes were polyuria, polyphagia, and polydipsia. Epidemiologically, it is predicted that Diabetes Mellitus in Indonesia will amount to approximately 21.3 million cases in 2030, and about 80% of these cases will be Type 2 Diabetes Mellitus. The prevalence of diabetic patients in Indonesia is the seventh highest, with 10 million cases, after China, India, and the United States. According to the Indonesian Basic Health Research in 2013, the prevalence of diabetes mellitus in Indonesia was 6.9% [2].

Obesity is one of the risks of diabetes, as obesity will lead to decreased sensitivity of hepatic and peripheral insulin, and the secondary phenomenon is a moderate increase of insulin secretion to overcome insulin resistance. Furthermore, central obesity increases this case. The indicator of obesity can be determined with the measurement of anthropometries, such as Body Mass Index (BMI), including body weight and height, waist circumference, and waist-hip ratio; these three aspects can measure central obesity. Anthropometric measurement is also a routine examination to determine the risk of metabolic diseases, one of which is diabetes mellitus [3]. Anthropometry is often used as a health indicator under normal conditions, as well as with athletes and diabetic patients [4–6]. Anthropometric measurements can be a controlled parameter for diabetes. A normal anthropometric value would explain that the patient has a good diet, exercise and take medication so that the patient would avoid complications. Several studies have suggested an association between anthropometry with BGL and a reduced risk of cardiovascular complications in diabetic patients [5, 6].

Higher BGL in diabetic patients is one of the risk factors for the occurrence of macro vascular disorders. According to the International Diabetes Federation, there are triad diseases of macro vascular disorders in people with diabetes mellitus: coronary heart disease, cerebrovascular disease, and peripheral vascular disease (PVD), including peripheral arterial disease (PAD) [7]. Based on the results of previous studies showing an increased incidence of PAD in diabetic patients, it is estimated that the prevalence of PAD in white males is 10.97 (OR: 2.15), and the prevalence in white females is 12.89 (OR: 2.73) [8]. Peripheral Arterial Disease is a risk for amputation of the inferior extremities, especially in patients with diabetes mellitus, and sufferers are at 2–5 times greater risk for cardiovascular disease and cerebrovascular events that are fatal and end in death. The quality of life of patients with DM and PAD will be disrupted due

to functional limitations and increasingly severe symptoms, and thus the productivity of working patients decreases [9]. Early detection of PAD is very important, especially in patients with diabetes, as early detection can limit the risk of myocardial infarct (MI) or stroke and reduce the morbidity and mortality rate of cardio-cerebrovascular disease and avoid the risks that can occur in patients with diabetes, such us ulcer, gangrene, amputation of inferior extremity due to ischemia, which will have an impact on functional limitations [10–12]. Early management of PAD in patients showed significant improvement in the quality of life [9, 13]. The Peripheral Arterial Disease diagnostic approach can be done through anamnesis, physical examination of palpation pulse arteria dorsalis pedis and arteria Tibialis posterior, as well as the measurement of ankle-brachial index (ABI) [11].

Peripheral Arterial Disease is a condition characterized by narrowing of the peripheral artery due to atherosclerosis, and it generally occurs in the arteries of the legs. The American College of Cardiology Foundation (ACCF) and the American Heart Association (AHA) recommend performing an ankle-brachial index (ABI) examination in patients with PAD risk factors, such as diabetes mellitus [9]. This procedure has a high sensitivity (79––95%) and specifications (95–96%) compared to angiography as a standard to determine the extent to which PAD events have occurred in patients at risk, including diabetes mellitus. The examination of the ankle-brachial index is a gold standard for non--invasive measurement of PAD detection and is recommended as part of an assessment of individuals at risk for the disease. The measurement of ABI is the first line of non-invasive screening and diagnosis of PAD [9].

Objectives

The purpose of this study was to analyze the relationship between anthropometry and ankle-brachial index with blood glucose level in patients with type 2 diabetes mellitus at the Tuntungan Community Health Center.

Material and methods

Study design

The study design was a cohort observational cross-sectional study.

Study location and respondents

The population of this study was all patients with type 2 diabetes. The reason for choosing Tuntungan Community Health Center as the study location was because it is one of the community health centers in Medan City which has wide area coverage and a dense population, as well as it is a place of study and was built by University of Sumatera Utara. Based on the data, the number of diabetes patients increases every month. The inclusion criteria were patients with type 2 diabetes in the working area of the Tuntungan Community Health Center aged 35–65 years, patients who have suffered from diabetes for at least one year, patients who visited the health center independently, and patients who were willing to participate in the research. On the other hand, the exclusion criteria were patients having experienced marked PAD by amputation of one of the extremities, patients experiencing terminal illness, diabetic patients with complications who could not visit the health center independently, and pregnant diabetic patients. The number of samples in this study was 101 patients, determined by a single sample formula for the hypothesis of the population proportion, while the samples were recruited utilizing the consecutive sampling method.

Before the research, this research protocol has been approved by the research ethics committee at the Faculty of Medicine Universitas Sumatera Utara, and all participants who are willing to participate in the research have signed written informed consent.

Measurements

The source of research data is primary data. Assessment of nutritional status was based on Body Mass Index (BMI), e.g. body weight and height measured at the time of research, waist or hip circumference determined with a tape measure, and ABI, determined with measurement of the highest systolic blood pressure from two extremities in the ankle and brachial areas. The data from the BGL was random glucose and from capillary blood. Measurement of BGL was performed just once (after anthropometric and ABI measurements). Blood glucose level was measured using a glucose-stick, and the capillary blood of the patient was taken and then read using a glucose-meter. The result of the blood glucose measurement is expressed in mg//dL. The reason of using capillary glucose level were that it was more easy, more simple, more convenient and more acceptable then venous glucose level, so it would be effective in monitoring and controlling the diabetes. Based on socio-economic factors, it is known that only a few patients have their own glucose-meter, thus a blood sugar examination is one reason for patients to come for treatment at the community health center. All patients participating in the study completed an informed consent form. Data was analyzed using the chi-square test with the SPSS computer program. The confidence interval was set at 95%, and a *p*-value of < 0.05 was considered significant.

Results

The number of patients who fulfilled the inclusion and exclusion criteria in this study was 101 patients in the Tuntungan Community Health Center, and the characteristics of the patients can be seen in Table 1.

Table 1. Basic characteristics of diabetes patients in the Tuntungan Community Health Center	Frequency (*n*)	Percentage (%)
Gender		
Male	57	56.4
Female	44	43.6
Age group		
Early adolescent (26–35 years old)	1	0.9
Late adolescent (36–45 years old)	25	24.8
Early elderly (46–55 years old)	52	51.5
Middle elderly (56–65 years old)	23	22.8
Duration of illness		
1–5 years	22	21.8
6–10 years	65	64.4
11–15 years	12	11.9
> 15 years	2	1.9
Family history		
Present (maternal)	50	49.5
Present (paternal)	39	38.6
Not present	12	11.9
Complaints often felt		
Numb foot	44	43.6
Weakness	11	10.9
Polyphagia	40	39.7
Polydipsia	2	1.9
Polyuria	4	3.9
Use of anti-diabetic drugs		
Glibenclamide	33	32.7
Metformin	68	67.3
Use of insulin		
Present	54	53.5
Not present	47	46.5

Table 1. Basic characteristics of diabetes patients in the Tuntungan Community Health Center

	Frequency (*n*)	Percentage (%)
Acanthosis nigricans		
Present	37	36.6
Not present	64	63.4
Ethnic groups		
Batak	35	34.7
Karo	28	27.7
Melayu	15	14.8
Padang	13	12.9
Jawa	10	9.9
Exercise		
Present	4	4.0
Not present	97	96.0
Blood pressure		
Hypertension	87	86.1
No hypertension	14	13.9
BMI		
Normal weight	16	15.8
Obese	85	84.2
Total	**101**	**100**

Based on Table 1, the number of male patients was higher than females with 57 people (56.4%). According to the age group, it is known that most of the respondents were classified as the early elderly group (46–55 years) with 52 people (51.5%), and about 65 patients (64.4%) have suffered from diabetes for 6–10 years. The number of patients who had a family history of diabetes mellitus, either from the father or mother, was 89 people (88.1%), while the complaints are often felt by patients was numb legs with 44 people (43.6%), followed by frequent hunger with 40 people (39.6%); 54 patients (53.5%) used insulin, whereas 47 patients (46.5%) did not use insulin; 33 patients (32.7%) consumed glibenclamide, while 68 patients (67.3%) consumed metformin. Among 101 diabetic patients, 37 people (36.6%) had acanthosis nigricans, the majority from the ethnic Batak people (35; 34.7%); and 97 patients (96%) did not perform regular exercise. About 87 patients (86.1%) also suffered from hypertension, and 85 patients (84.2%) were found to be obese.

According to Table 2, 62 patients (61.4%) had a waist circumference at risk, and 32 patients (31.6%) were classified into the hyperglycemic group. 62 patients (61.4%) had an at-risk waist-hip ratio, but only 20 of them (19.8%) were classified into the hyperglycemic group. Based on the examination of upper arm circumference, it was found that 27 patients (26.7%) were found to be obese, as the value of upper arm circumference was above 32 cm; 9 (8.9%) of them were classified into the hyperglycemic group. The number of diabetic patients with obesity classified into the hyperglycemic group was 36 patients (35.6%), and 87 patients (86.1%) also suffered from hypertension, in which 28 of them (27.7%) were classified into the hyperglycemic group. The number of diabetic patients with a decreased ABI value classified into the hyperglycemic group was 2 patients (1.9%).

The chi-square test results showed that there was a relationship between waist circumference, BMI, and ABI with BGL ($p = 0.0001$; $p = 0.001$; $p = 0.0001$), whereas no relationship was found between waist-hip ratio, upper arm circumference, and blood pressure with BGL ($p = 0.37$; $p = 0.481$; $p = 0.07$).

Discussion

Based on the demographic characteristics of the patients, 89 patients had a family history of diabetes. Previous studies have suggested that a person who has a family history of diabetes was significantly and independently associated with diabetes, and they are 2–6 times more at risk of developing diabetes. Furthermore, people with a family history of diabetes are at risk of having higher BMI (overweight, obese) and highest average blood glucose [14–17]. This is because individuals with a genetic predisposition to diabetes show a lower beta-cell compensation response to decreased insulin sensitivity associated with obesity [15, 17]. These findings help explain the multiplication effect

Table 2. The relationship between anthropometry and ABI with blood glucose level in patients with diabetes in the Tuntungan Community Health Center

	Blood glucose level		Total (%)	*p*
	Normal (%)	Hyperglycemia (%)		
Waist circumference				
Risk (♀: > 80 cm; ♂: > 90 cm)	30 (29.7)	32 (31.6)	62 (61.4)	0.0001
Not at risk (♀: ≤ 80 cm; ♂: ≤ 90 cm)	35 (34.6)	4 (4)	39 (38.6)	
Waist-hip ratio				
Risk (♀: ≥0.80; ♂: ≥0.95)	42 (41.5)	20 (19.8)	62 (61.4)	0.37
Not at risk (♀: <0.80; ♂: <0.95)	23 (22.7)	16 (15.8)	39 (38.6)	
Upper arm circumference				
Obese (> 32 cm)	18 (17.8)	9 (8.9)	27 (26.7)	0.481
Good nutrition (< 32 cm)	47 (46.5)	27 (26.7)	74 (73.3)	
BMI				
Obese (≥ 23)	49 (48.5)	36 (35.6)	85 (84.1)	0.001
Normal weight (18.5–22.9)	16 (15.9)	0 (0)	16 (15.9)	
Blood pressure				
Hypertension (≥ 130/90)	59 (58.4)	28 (27.7)	87 (86.1)	0.07
Normal (< 130/90)	6 (5.9)	8 (7.9)	14 (13.9)	
ABI				
Decrease (< 0.90)	26 (25.7)	2 (1.9)	28 (27.7)	0.0001
Normal (0.91–1.30)	39 (38.6)	34 (33.6)	73 (72.3)	
Total	**65 (64.3)**	**36 (35.6)**	**101 (100)**	

of family history and obesity on the risk of type 2 diabetes [16]. Between the father and mother, they presented equivalent risk ratios for type 2 diabetes [12, 17].

About 37 diabetic patients (36.6%) had acanthosis nigricans. The incidence rate for acanthosis nigricans is not exactly known. However, it is found that obesity is closely associated with acanthosis nigricans, and more than half of the adults with body weight over 200% of the ideal body weight had acanthosis nigricans [18]. Acanthosis nigricans is said to be associated with race and is commonly found in people with dark skin. The prevalence in Caucasians is less than 1%, while the prevalence in Latinos is 5.5%, and in Africans, it is 13.3%. In this study, the incidence of acanthosis nigricans was most likely influenced by nutritional status and not by ethnicity/race, as all of the diabetic patients' ethnicity/race, is generally in the same scope (Mongoloid).

The results showed that 61.4% of the patients had a waist circumference in the category of risk. The factor of age and less physical activity in diabetic patients causes changes in the proportion of fat and muscle in the body. The older a person, the more body fat, less muscles and less physical activity cause the muscle mass decreased, so that the use of blood sugar is reduced, and the resulting blood sugar tends to increase in this group [19–21]. The chi-square test showed that there was a relationship between waist circumference and BGL. The relationship between waist circumference and BGL had a positive pattern trend, which means that the larger the waist circumference, the higher the blood sugar level. An excessive increase in visceral fat can decrease adiponectin production. Decreased adiponectin may increase the risk of metabolic disorders, such as insulin resistance, which can affect hyperglycemia [6, 20–24].

In this study, it was found that there was no significant relationship between waist-hip ratio and BGL ($p = 0.370$). Waist-hip ratio is often used as a measure of central/abdominal obesity, and central obesity suggests a change in the homeostasis of glucose-insulin in the body, which can lead to accumulation of fatty tissue. The results of this study were not in line with previous research, which found that there was a relationship between waist-hip ratio and BGL [6, 25]. These differences may be due to differences in the age groups, as age differences might determine body composition, which affects the distribution of muscle mass and total body fat [23, 26]. A majority of the patients in this study were within the age of 46–55 years, while previous studies recruited younger patients.

There was no relationship between upper arm circumference and BGL in diabetic patients in the Tuntungan Community Health Center (chi-square test with p-value = 0.481). Previous studies showed that there was a positive correlation between upper arm circumference and BGL in diabetic patients [19–22]. This might be due to differences in the selection of cut-off points in this study, making the result different from previous studies [23, 26].

A significant association between BMI and average BGL was found ($p = 0.001$). Body Mass Index is an indicator for evaluating obesity and overweight in adults. About 70% of diabetic patients are overweight, and more than 50% of obese patients undergo a decrease in glucose tolerance, which causes hyperglycemia and may affect BMI [6, 20–25]. BMI as a measure to determine obesity has some limitations. Firstly, BMI cannot distinguish between fat mass and lean body mass. Another weakness is that BMI highly depends on age, gender, and ethnicity. One of the risk factors for type 2 diabetes is central obesity, where visceral/ /abdominal fat is more unstable and has higher access to circulation; thus, it is more likely to cause morbidity and decrease the quality of life. Body Mass Index has a strong relationship with diabetes and insulin resistance. In obese individuals, the amount of non-esterified fatty acids, glycerol, hormones, cytokines, proinflammatory markers, and other substances that are involved in the development of insulin resistance is increased. The pathogenesis in the development of diabetes is based on the fact that the β-islet cells of the pancreas are impaired, causing a lack of control of blood glucose. The development of diabetes becomes more inevitable if the failure of β-islet cells of the pancreas is accompanied by insulin resistance. Weight gain and body mass are central to the formation and rising incidence of type 1 and type 2 diabetes [27].

The study showed no significant relationship between blood pressure and average BGL ($p > 0.05$). This result is different from literature that states that hypertension is a comorbid condition, which is commonly found in both type 1 or 2 diabetes. The American Diabetes Association reported that 71% of diabetic patients had a blood pressure of 140/90 mm Hg or more from 2000 to 2012 [22, 28]. When an individual has both hypertension and diabetes, the side effect of either one disease can worsen the condition of the other disease. This is because both hypertension and diabetes have the same risk factors, including overweight and less active lifestyle [5, 26, 31, 32]. A study conducted in Morocco showed that 70.4% of patients with type 2 diabetes had hypertension as well. This study might explain the different frequency of each country, which is caused by different surveillance methods, a difference definition of hypertension, population characteristics, and ethnic variations [28, 33, 34]. No relationship was found between blood pressure and average BGL in this study, which might be due to other factors, such as age. It is known that age becomes a risk factor for the increase in blood pressure [35].

Based on this study, we found that there was a significant relationship between ABI and BGL ($p = 0.0001$), which means that there was a significant decrease in the value of ABI in people with diabetes mellitus. This condition occurs due to endothelial dysfunction and the condition of atherosclerosis due to hyperglycemia, resulting in narrowing of the lumen of the blood vessels up to the periphery [11, 29]. Lumen reduction leads to decreased peripheral circulation; this circulation deficit causes a decrease in the ankle-brachial index (ABI) value [30, 31, 36––38]. This condition is characterized by frequent complaints of numbness in the extremities, as in most of the complaints experienced by 44 patients (43.6%).

Limitations of the study

Firstly, this study was a cross-sectional study; therefore, this study was not able to check the history of the disease and the problems experienced by the patients from the beginning of diabetes, including the nutritional status of the patients. Furthermore, this research did not differ diabetes patients with a risk of vascular disorders, such as smoking, hyper-cholesterol, and other diseases which can clog the leg veins; thus, the results were less specific. Secondly, an examination of patients with diabetes is the only available examination at primary level service, such us random BGL, anthropometry, and blood pressure, and thus HbA_{1c} examination, which is one of the specific and objective specific control parameters for diabetic patients, is not performed, as this was not available here. In the future study, we plan to measure the HbA_{1c} level and lipid profile of type 2 diabetes patients at the Tuntungan Community Health Center. Thirdly, this study was conducted in only one working area of the community health center in Medan city, so that the number of patients was only limited to patients with type 2 diabetes who came to the community health center. Even there were not specific inclusion and exclusion criteria instead of general health condition of the diabetes patients, this study provide important issue about the condition of diabetes patients that need to be studied in the future with better study design.

Conclusions and recommendations

From the results of the study, it can be seen that there is a relationship between dietary regulation with BGL control, where uncontrolled BGL was very closely related to complications experienced by patients, such as macro vascular complications.

It is recommended to family doctors working in primary care: Firstly, to improve education and enhance the understanding and independence of diabetes patients, and thus the patients will be able to manage the disease independently. Secondly, to carry out periodic ABI examinations to prevent and make early diagnosis of PAD in people with type 2 diabetes mellitus, as early efforts can improve the prognosis and progression of the disease, as well as prevent further complications that can decrease the quality of life of the patient.

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