ORIGINAL ARTICLE

The relationship between infection severity, wound categorization, and foot care in type 2 diabetes mellitus patients with recurring diabetic foot ulcers

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ABSTRACT

Introduction: Research on diabetic foot ulcers (DFU) infection is limited to the first wound. Therefore, this study aimed to evaluate the relationship between wound classification (Wagner and SHID), and foot care against severity infection of DFU recurrent that may contribute to an increased susceptibility to infection among individuals with recurrent DFUs.

Materials and Methods: A cross-sectional design was used in this study involving 245 participants of type 2 diabetes mellitus (T2DM) was conducted at a Kitamura Wound Care Clinic, PKU Muhammadiyah, located in Pontianak, West Kalimantan, Indonesia, between September 2022 and February 2023. The Kruskal-Wallis test was used to assess the relationship between the foot care practices and infection status. A linear regression test to examine the independent risk factors.

Results: Wounds' characteristics regarding foot care practice group were significantly including more than 5 months wound heal from previous wounds ($p = 0.045$), the percentage of wound site on dorsal was higher in the foot care practice group ($p < 0.001$), the percentage had no deformity feet was higher in the foot care practice group ($p < 0.001$), the percentage had no previous amputation feet was higher in the foot care practice group ($p < 0.001$). Also, the percentage had grade three was higher in the foot care practice group ($p < 0.001$), the percentage had grade three was higher in the foot care practice group ($p < 0.001$), and the percentage had mild infection status was higher in the foot care practice group ($p < 0.001$). The predictors of diabetic foot infection were Wagner and SHID classification and foot care ($p < 0.001$, $p < 0.001$, and $p < 0.01$) respectively.

Conclusion: This study demonstrated that foot-care behaviour in diabetic patients in Indonesia is poor. In addition, this study also has shown Wagner grading, SHID grading, and foot-care are predictors of infection in recurrent DFUs.

KEYWORDS:
Diabetic foot; diabetic foot infection; recurrent; predictor

INTRODUCTION

According to International Diabetes Federation (IDF) data, the number of diabetes mellitus (DM) patients in Indonesia is expected to increase to 16.7 million by 2045, up from 10.3 million in 2017.[1] According to these estimates, Indonesia will rank as the sixth-highest country in terms of the number of DM cases worldwide.[1] This raises worries regarding an increase in diabetic foot ulcers (DFUs), one of the consequences of diabetes.

DFUs are one of the most common problems in diabetics. These ulcers can cause physical limitations and a decrease in DM patients' quality of life.[2–4] Additionally, DFUs exhibit an increased risk for infection, with varying degrees of severity.[5] Infections in DFUs, if not managed appropriately, can lead to more serious complications, such as limb amputation.

Periphery arterial disease (PAD) is a major risk factor for DFUs and a strong risk factor for DFU in diabetics.[6,7] Nearly half of patients have PAD, which raises the risk of infection, non-healing ulcers and amputations.[8] In addition, neuropathy is one feature of DFU's.[9] The development and progression of infections, ischemic ulcers and gangrene in diabetics is facilitated by the interaction of metabolic variables, immunopathy, diabetic neuropathy and diabetic angiopathy.[10]

Based on a study conducted, it has been determined that the incidence rate of DFU infection is approximately 25.2%.[11] Furthermore, a separate investigation revealed that around 56% of DFUs exhibit signs of infection, with approximately 20% of these cases ultimately leading to the need for lower limb amputation.[12] However, it is worth noting that DFUs have the potential to recur. According to a prior investigation, the prevalence of recurrent infection in DFUs was reported to be 40%.[13]

Identifying an infection is one part of the DFU's assessment that can be done by assessing risk factors for infection and paying attention to signs and symptoms.[13] According to one study, the independent risk factor could happen for DFU patients who were healed between 3 to 12 months, experienced peripheral neuropathy, foot deformity, younger age and female gender, presented deep DFUs, or had a history of DFUs.

This article was accepted: 12 January 2024
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DFUs with infections can interfere with mobility.[14,15] Lack of physical mobility will affect the patient's daily activities. This leads to depression and increased costs, thereby reducing quality of life. Other studies show that patients with DFUs will be more angry, frustrated, depressed and helpless compared to patients with DM.[16–18] Based on some of these studies, it can be concluded that patients with DFU infections can lead to declining quality of life.

Recurrent infections in DFUs imply a more complicated problem. Infections on DFUs imply a more complicated problem. The understanding of factors that contribute to the occurrence of infections in DFUs, particularly recurrence, developing efficient prevention and management methods requires an understanding of the risk variables that contribute to recurrent DFU infections.

Currently, research on risk factors for DFU infection is limited to only the first wound, and no risk factors have been found for recurrent DFU infections. Therefore, the purpose of this study is to evaluate relationship between wound classification, foot-care against severity infection DFUs. As a result, the findings of this study are likely to guide healthcare practitioners in developing effective interventions to reduce the risk of infection in DFUs and to improve the quality of life for DM patients.

MATERIALS AND METHODS

Study Design and Participants

A cross-sectional design was used in this study. We followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

Setting

This study was conducted on type 2 diabetes mellitus (T2DM) patients registered at the Kitamura Wound Care Clinic, PKU Muhammadiyah, located in Pontianak, West Kalimantan, Indonesia, between September 2022 and February 2023.

Study Participants

The sample selection is based on the non-random criteria, and not every person/individual of the population has a chance of being included. A few parameters were used to calculate the sample size and the estimated sample size for this study was 245 participants, and used sample size calculation by Raosoft.[19] The inclusion criteria are above age 18 years with result of grade 2 to 4 Wagner system. Participants who did not match the specified criteria were excluded from the study. Before beginning the study, informed consent was properly obtained from each patient's family. Patients that were excluded from the study were those who had physical limitations, cognitive or neurological impairments, and serious illnesses or consequences.

Observational data

The demographic questionnaire consisted of information such as age, gender occupation and medical history. The clinical information include body mass index, glycemia status, smoking habits, alcohol consumption, treatment methods neuropathy status assessed using the 10 g (5.07 Semmes-Weinstein) monofilament, ankle-brachial index (ABI) and foot care behaviour evaluated using the Nottingham Assessment of Functional Footcare (NAFF). The validity and reliability test results obtained the value of r = 0.357–0.765 and the Cronbach alpha value obtained was 0.791.[20] The clinical data encompassed several aspects related to the wounds, such as their duration, location, presence of foot deformity and history of prior wound healing. The severity of the wounds also was assessed using SHID.[21] SHID classification includes the first classification describes the superficial area that covers the dermis and/or epidermis layer. The second classification includes only the presence of one or more indications or symptoms of an infection and/or inflammation, such as osteomyelitis or ischaemia. The third classification includes tissue damage that affects the subcutaneous layers of the lower dermis and extends to tendon tissue, excluding bone. The fourth classification covers tissue damage areas including subcutaneous, muscle, fascia/tendon and those with one or more indications of osteomyelitis, ischemia, infection or inflammation. The fifth classification includes damage to all skin tissue that penetrates the bone, including tissues that have experienced both localised and severe gangrene. With the inclusion of any one or more of the following indicators, the sixth classification is comparable to the fifth classification: osteomyelitis, inflammation, infection and ischemia.[22] SHID has previously studied the content validity and reliability of this tool, which were 0.72[21] and 0.81[22] respectively. Also, in this study we used the Wagner classification. The Wagner classification system is an early framework for classifying DFUs. It evaluates the depth of the ulcer and the presence of osteomyelitis or gangrene and divides the ulcers into six levels.[23] In order to assess the extent and severity of the infection, the researcher collaborated with a team of qualified wound-care specialists.

Ethical considerations

The study was approved on Feb 23th 2023 by The Institute of Technology and Health of Muhammadiyah West Kalimantan committee with serial number No. 61/II.I.AU/KET.ETIK/III/2023.

Data analysis

Descriptive statistics were performed to identify the categorical variables. The Kruskal-Wallis test was used to assess the relationship between foot care practices and infection status. For the independent risk factor, binary logistic regression test is used to estimate the relationship between wound classification (Wagner and SHID), and foot-care against severity of diabetic foot infection. Data were analysed using SPSS software (version 26.0; IBM Corp., Armonk, NY, USA), and $p < 0.05$ was chosen as the level of significance.

RESULTS

Foot care practice

Table I findings indicated that 175 participants examined their feet, while 207 participants checked their shoes before putting them on. While checking shoes when taking them off, 199 participants were checking their feet. 194 participants were washing their feet, while 105 participants were drying their feet after washing them, drying between toes were 178 participants, using moisturising cream on feet were 42 participants, cutting toenails were 79 participants,

Table I: Foot care practice by Nottingham assessment of functional footcare (n = 254)

Variables	F	%
Frequency examining feet		
More than once a day	98	40.0
Once a day	77	31.4
2-6 times a week	58	23.7
Once a week or less	12	4.9
Checking shoes before put them on		
Often	118	48.2
Sometimes	89	36.3
Rarely	31	12.6
Never	7	2.9
Checking shoes when take them off		
Often	102	41.6
Sometimes	97	39.6
Rarely	38	15.5
Never	8	3.3
Frequency washing feet		
More than once a day	124	50.6
Once a day	68	27.7
Most days a week	44	18.0
A few days a week	9	3.7
Drying feet after wash		
Often	105	54.1
Sometimes	70	36.1
Rarely	17	8.8
Never	1	0.5
Drying between toes		
Always	75	30.6
Often	103	42.1
Sometimes	11	4.5
Never	56	22.8
Frequency using moisturising cream on feet		
Daily	15	6.1
Once a week	27	11.0
About once a month	124	50.6
Never	79	32.3
Cutting toenails		
About once a week	20	8.2
About once a month	59	24.1
Less than once a month	153	62.4
Never	13	5.3
Wearing shoes with lace-up, Velcro or strap fastenings		
Most of the time	48	19.6
Sometimes	102	41.6
Rarely	69	28.2
Never	26	10.6
Wearing pointed-toes shoes		
Most of the time	13	5.3
Sometimes	106	43.2
Rarely	56	22.9
Never	70	28.6
Wearing artificial fibre socks		
Most of the time	17	6.9
Sometimes	93	37.9
Rarely	95	39.0
Never	30	12.2
Wearing shoes without socks/stocking/tights		
Never	16	6.5
Rarely	63	25.7
Sometimes	130	53.1
Often	36	14.7
Using a dry dressing on a blister when get one		
Never	53	21.6
Rarely	120	49.0
Sometimes	51	20.8
Often	21	8.6
Foot care practice		
Good	80	32.6
Poor	165	67.4

Data were presented frequency and percentage

Table II: Participants' characteristics regarding foot care

Characteristics	Foot care practice		Total	p value
	Good (n = 80)	Poor (n = 165)		
Sex, no. (%)				0.012*
Female	51 (39.8)	77 (60.2)	128	
Male	29 (24.68)	88 (75.2)	117	
Age, years (%)				0.004**
< 30	14 (93.3)	1 (6.7)	15	
31-39	9 (29.0)	22 (71.0)	31	
40-49	10 (20.8)	38 (79.2)	48	
>50	47 (31.1)	104 (68.9)	151	
BMI, kg/m^2 (%)				0.562
<18.5	4 (25.0)	12 (75.0)	16	
18.5-24.9	42 (30.9)	94 (69.1)	136	
25.0-29.9	28 (38.9)	44 (61.1)	72	
>30	6 (28.6)	15 (71.4)	21	
Duration of DM (years)				0.809
<1	7 (29.2)	17 (70.8)	24	
1-5	39 (35.5)	71 (64.5)	110	
6-10	22 (32.4)	46 (67.6)	68	
>10	12 (27.9)	31 (72.1)	43	
Married status, no (%)				<0.001***
Married	63 (30.7)	142 (69.3)	205	
Widow	2 (8.7)	21 (91.3)	23	
No	15 (88.2)	2 (11.8)	17	
Occupation status, no (%)				0.032*
Civil service	14 (58.3)	10 (41.7)	24	
Private	28 (35.4)	70 (64.6)	98	
Housewife	30 (32.6)	62 (67.4)	92	
Retired	6 (22.2)	21 (77.8)	27	
No	2 (50.0)	2 (50.0)	4	
Education level, no (%)				0.012*
Undergraduate	0 (0.0)	22 (100.0)	22	
Diploma	11 (35.5)	20 (64.5)	32	
Senior high school	2 (20.0)	8 (80.0)	10	
Yunior high school	22 (32.4)	46 (67.6)	68	
Elementary school	45 (39.8)	68 (60.2)	113	
Blood sugar check routinely, no (%)				0.646
Yes	64 (32.0)	136 (68.0)	200	
No	16 (35.6)	29 (64.4)	45	
Smoking, no (%)				<0.001***
None	73 (39.0)	114 (61.0)	187	
Smoker	7 (12.1)	51 (87.9)	58	
Alcohol consumption, no (%)				<0.001***
Yes	1 (3.0)	32 (97.0)	33	
No	79 (37.3)	133 (62.7)	212	
Physical activity routinely, no (%)				0.515
Yes	45 (31.0)	100 (69.0)	145	
No	35 (35.0)	65 (65.0)	100	
Comorbid, no (%)				0.718
Yes	48 (33.6)	95 (66.4)	143	
No	32 (31.40)	70 (68.6)	102	

BMI, body mass index; DM, diabetes mellitus; n, number of participants; *p < 0.05, **p < 0.01, ***p < 0.001

wearing shoes with lace-up, Velcro or strap fastenings were 150 participants, wearing pointed-toes shoes were 119 participants, wearing artificial fibre socks were 110 participants, wearing shoes without socks/stocking/tights were 166 participants, using a dry dressing on a blister when get 72 participants. Regarding foot care practice, 80 participants were good and 165 participants were poor.

Participants' characteristics regarding foot care

A total of 245 patients participated in the present study were identified using non-probability-purposive sampling techniques, consisting of all individuals who had DFUs (Figure 1). The participants' characteristics are summarised in Table II. We found that participants in foot care practice group were significantly older than those without (p = 0.004), female were more common in the foot care practice group (p = 0.012), the number of married participants was higher in the foot care practice group (p < 0.001), the number of participants with private worker was higher in the foot care practice group (p = 0.032), the number of participants with elementary school was higher in the foot care practice group (p = 0.012). Also, the number of participants with no smoking

Table III: Wounds' characteristics regarding foot care

Characteristics	Foot care Practice		Total	p value
	Good (n = 80)	Poor (n = 165)		
Wound onset from previous wound, years (%)				0.192
<1	12 (22.6)	41 (77.4)	53	
1-5	45 (34.4)	86 (65.6)	131	
>5	23 (37.7)	38 (62.3)	61	
Month from last ulcer healed, no (%)				0.045*
< 1	1 (9.1)	10 (90.9)	11	
1-5	18 (25.4)	53 (74.6)	71	
>5	61 (37.4)	102 (62.6)	163	
Wound site, no (%)				<0.001***
Toe	31 (47.7)	34 (52.3)	65	
Metatarsal	18 (40.0)	27 (60.0)	45	
Dorsal	12 (20.0)	58 (80.0)	70	
Heel	1 (8.3)	11 (91.7)	12	
Plantar	16 (20.0)	37(80.0)	53	
Neuropathy, no (%)				0.101
Yes	51(29.5)	122 (70.5)	173	
No	29 (40.3)	43 (59.7)	72	
PAD, no (%)				0.354
Yes	46 (30.5)	105 (69.5)	151	
No	34 (36.2)	60 (63.8)	94	
Deformity feet, no (%)				<0.001***
Yes	4 (9.3)	39 (90.7)	43	
No	76 (37.6)	126 (62.4)	202	
Previous amputation, no (%)				<0.001***
Yes	5 (10.6)	42(89.4)	47	
No	75 (37.9)	123 (62.1)	198	
Wagner grading, no (%)				0.001**
Grade 1	19 (55.9)	15 (44.1)	34	
Grade 2	15 (34.1)	29 (65.9)	44	
Grade 3	46 (30.5)	105 (69.5)	151	
Grade 4	0 (0.0)	16 (100.0)	16	
SHID grading, no (%)				0.003**
Grade 1	10 (71.4)	4 (28.6)	14	
Grade 2	11 (50.0)	11 (50.0)	22	
Grade 3	50 (31.6)	108 (68.4)	158	
Grade 4	5 (20.8)	19 (79.2)	24	
Grade 5	4 (14.8)	23 (85.2)	27	
Infection status, no (%)				<0.001***
Heavy	7 (11.5)	54 (88.5)	61	
Mild	73 (39.7)	111 (60.3)	184	

PAD, peripheral arterial disease; N, number of participants; *p < 0.05, **p < 0.01, ***p < 0.001,

Table IV: Multivariate binary logistic regression analysis relationship between Wagner and SHID classification, and foot care to severity of infection in diabetic foot ulcers (n = 254)

	B	S. E.	Wald	df	Sig.	Exp(B)
Wagner	2.511	0.534	22.144	1	<0.001***	12.321
SHID	1.626	0.251	42.052	1	<0.001***	5.084
Footcare	1.382	0.412	11.240	1	0.001**	3.983
Constant	-14.193	2.058	47.558	1	<0.001***	0.000

** p < 0.01; p<0.001***

(p < 0.001) and alcohol consumption (p < 0.001). Therefore, this study showed that the foot care practice was done by older females with a private worker who had already gotten married, has an education in elementary school, no smoking, and no alcohol consumption.

Wounds' characteristics regarding foot care practice

We found that participants in the foot care practice group were significantly more than 5 months away from healing their previous wounds (p = 0.045), the number of wounds site on dorsal were higher in the foot care practice group (p < 0.001), the number of participants who had no deformities in their feet was higher in the foot care practice group (p < 0.001), the number of participants who had no previous amputation feet were higher in the foot care practice group (p < 0.001). Also, the number of participants who had grade 3 on Wagner classification were higher in the foot care practice group (p < 0.001), and the number of participants

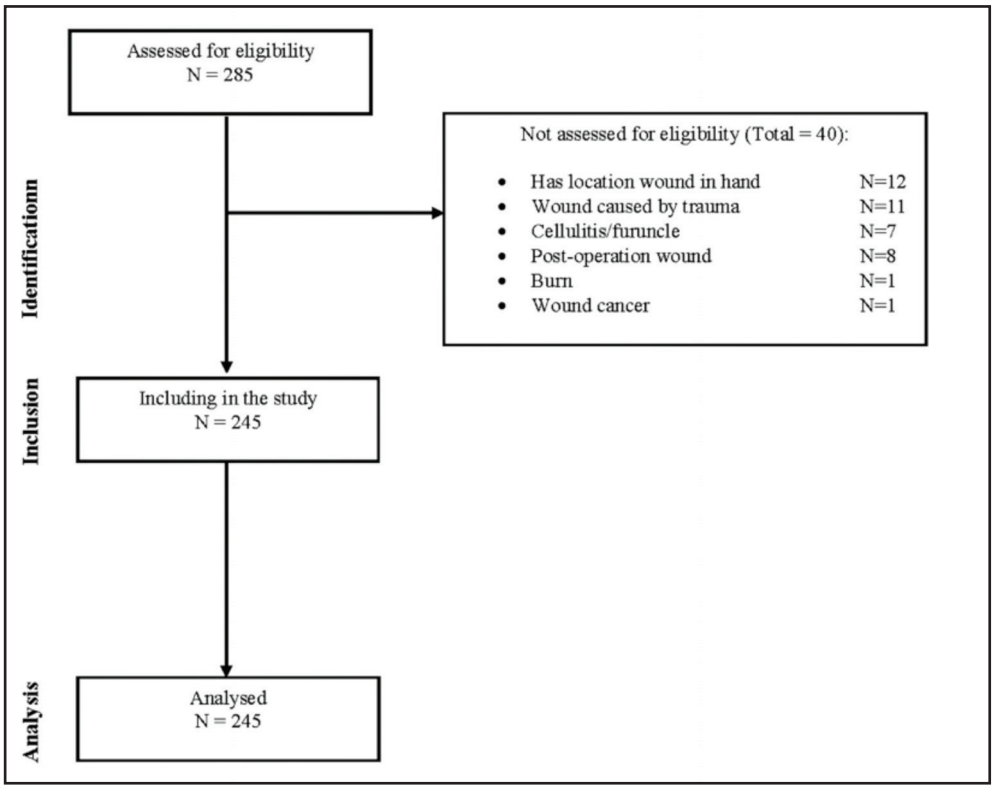

Fig. 1: Strengthening the reporting of observational studies in epidemiology flow chart of the participant enrolment process.

who had mild infection status were higher in the foot care practice group ($p < 0.001$) (Table III). Therefore, this study showed that the foot care practice group were done in a group whose wound healed for more than 5 months at the dorsal location, had no deformity on the foot, had a grade 3 on Wagner classification, and had a mild infection.

Predictors of the severity of infection in DFU

A binary logistic regression shown there was correlation between Wagner, SHID classification and foot care against the severity of infection in DFUs ($p < 0.001$, $p < 0.01$, and $p< 0.001$) respectively (Table IV).

DISCUSSION

Foot care practice is the most important goal to achieve better DFUs care. Analysis of risk factors for infection in recurrent DFUs and self-care foot practice of T2DM patients.

According to the finding, the risk factors infection on DFUs recurrent in Indonesia were wearing shoes with lace-up, Velcro or strap fastenings and wearing pointed-toes shoes. To the best of our knowledge, this is the first study to determine and investigate the factors that may contribute to an increased susceptibility to infection among individuals with recurrent DFUs.

According to the finding, 80 (32.6%) participants with DM had good diabetic foot self-care and consistent with the study of Ethiopia (39.8%).[24] The prevalence of diabetic foot self-care was lower than in Iran (51.4%),[25] and Malaysia (40.4%).[26] However, this is higher than the study done in Turkey (20.8%).[27] The observed disparities can be attributed to variations in the educational attainment levels of the participants in the study. Previous study reported that the status of foot self-care was influenced by education level.[27,28] Also, there are differences in the outcome variables. For example, the study conducted in Turkey used categories of foot self-care as bad, moderate and good, whereas in our study, self-care practice was categorised as poor or good.

In this study, 71.4% of patients inspected their feet daily or more than once daily. This result is higher than study conducted in Turkey (68.6%)[27], and Malaysia (62.7%)[26] compared with studies in Ethiopia (94.7%).[24] About 192 (77.7%) patients washed their feet daily and more than once daily. This result is higher than the study conducted in Turkey (67.4%)[27] compared with studies in Malaysia 93.8%,[26] and Ethiopia (98.7%).[24] About 207 (84.5%) patients often and sometimes checked their shoes before putting them on, consistent with the study of Malaysia (81.6%).[26] This result is higher than the study conducted in Ethiopia (75.3%),[29] and Turkey (56.3%).[27] About 175 (90.2%) patients often and sometimes dry their feet after washing. This result is higher than the study conducted in Ethiopia (16.5%).[29] About 178 (72.7%) patients always and often dry their feet (between toes) which is consistent with the study of Malaysia (74%).[26] About 42 (17.1%) patients used moisturising cream on feet. This result is lower than the study conducted in Ethiopia (25.5%),[29] Malaysia (45.4%),[26] and Turkey (26.8%).[27] About 79 (32.3%) patients cut their toenails once a week or once a month. This result is higher than the study conducted in Ethiopia (29.6%).[29] About 166 (67.8%) patients often and sometimes wear shoes without socks, which is consistent with

the study of Malaysia (63.3%).[26] However, this result is higher than the study conducted in Ethiopia (34.5).[29] This might be due to the differences in knowledge level and education status. According to a previous study, education status has a significant effect on knowledge.[27] This is because if diabetic patients have good knowledge of foot self-care then they will be able to improve their foot practice.[24]

Our study found that smoking was one of the predictors of diabetic foot infection. The result is consistent that smoking has been identified as a significant risk factor for the development of infections in diabetic foot, largely attributed to its detrimental effects on blood circulation and impaired wound healing.[30–32] A systematic review reported that smoking is a risk factor for the recurrence of DFU.[33,34] In addition, a previous study reported that recurrence was a risk factor for foot infection.[35] Therefore, smoking can lead to the recurrence of DFU, which is a risk factor for infections in DFUs.

Another finding from our study was that deformity of feet is a predictor of diabetic foot infection. Foot deformities in diabetic patients can lead to abnormal pressure distributions, causing ulcerations that are at risk of infection, especially when combined with other complications like neuropathy and impaired circulation. The combination of reduced sensation, abnormal foot structure and compromised blood flow creates a conducive environment for the development and recurrence of infections.[35] This result consistent with a previous study that conducted on patients with recurrent DFUs found a significant association between foot deformity and the occurrence of infections in the ulcers.[36] Therefore, foot deformities play a crucial role in the development and recurrence of DFUs. The combination of pressure abnormalities, reduced sensation, impaired circulation and shoe-fit issues can lead to wounds that are more susceptible to infections. Proper foot care, including addressing deformities and ensuring optimal shoe fit, is critical in preventing complications in individuals with diabetes.

Another finding shown in Wagner and SHID grading was a predictor of diabetic foot infection. This result is consistent with previous study that reported that Wagner grade III/IV was a risk factor for the recurrence of DFUs,[33] and recurrence is a risk factor in diabetic foot infection.[35] As we know, the Wagner grading system is commonly used to classify the severity of DFUs, with higher grades typically associated with more severe complications, including infection. Consistent with our study, the predominant data was for Wagner grades III. Interestingly, both the Wagner and SHID grading results were predominantly at grade III. SHID grading also used to classify the infection of DFU with good validity (0.72%),[21] and reliability (0.81 to 1.00).[22]

The present study has some limitations and strengths. Firstly, due to this study being cross-sectional, it can be difficult to identify the causal factors. Secondly, this study was carried out in Indonesia, results cannot be generalised to other countries. Meanwhile, the strength of this study is less research on DFUs conducted in Indonesia and most of them conducted in the western and middle east countries with different population background, and the first study to reveal that SHID grading is predictor for infection in recurrent DFUs.

Clinical implications

It was important to identify the associated factors of DFUs as early as possible to allow early interventions and develop new practice guideline and strategies. Sufficient knowledge, and information will lead them to decrease an ability to do self-care towards their DFUs. A campaign awareness and educational programs related to foot-care should be implemented as preventive strategies to prevent infections in diabetic foot.

CONCLUSION

This study may contribute to a greater knowledge of associated factors of risk for infection in recurrent diabetic foot ulcers (DFUs) especially type 2 diabetes mellitus in maintaining good health practice. Thus, continued efforts and reminders need to be given to those recurrent DFUs on predictors of infection such as Wagner grading, SHID grading and foot-care.

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