

Skin hydration of the heel with fissure in patients with diabetes: a cross-sectional observational study

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Purpose: Foot fissure should be prevented in patients with diabetes due to the likelihood of subsequent diabetic ulcer. The purpose of this study was to investigate a cutoff point for skin hydration with fissure and the factors associated with low skin hydration in patients with diabetes.

Subjects and methods: Subjects were patients with diabetes who visited the diabetic foot clinic and were evaluated for skin hydration on the heel between April 2008 and March 2015. Information about fissure, skin hydration, age, sex, autonomic neuropathy, angiopathy, and tinea pedis were collected from the medical charts. Skin hydration on the heel was measured using a moisture checker. Skin hydration was compared between heels with and without fissure, and a cutoff for skin hydration with fissure was determined using receiver operating characteristic analysis. Based on the determined cutoff, factors associated with lower skin hydration were analyzed using logistic regression analysis.

Results: Participants comprised 693 patients. Mean±SD age was 66.8±10.8 years, and 57.0% of subjects were male. The frequency of fissures on the heels was 10.4%. Area under the receiver operating characteristic curve for skin hydration in the presence of fissure was 0.717. Twenty percent was selected as the cutoff point, offering sensitivity of 0.478 and specificity of 0.819. Logistic regression analysis showed correlations between three factors (male sex, tinea pedis, and room temperature) and skin hydration <20.0% (odds ratio [OR] 1.587, 95% CI 1.157–2.178, $p=0.004$; OR 1.548, 95% CI 1.122–2.135, $p=0.005$; and OR 0.900, 95% CI 0.823–0.985, $p=0.021$, respectively).

Conclusion: To prevent heel fissures, moisturizing care should aim at achieving skin hydration of 20%. If skin hydration is <20%, prevention of fissures may warrant not only specialized moisturizing care but also consideration of treatment for tinea pedis.

Keywords: xerosis, diabetes mellitus, tinea pedis, moisturizing care

Introduction

Diabetic foot is one of the complications of diabetes mellitus, representing infection, ulceration, or destruction of tissues of the foot associated with neuropathy and/or peripheral artery disease in the lower extremity of people with diabetes.¹ Once diabetic foot develops, physical condition, long-term prognosis,^{2,3} and quality of life^{4,5} are severely affected. The number of patients with diabetes is estimated to increase,⁶ and establishment of preventive care for diabetic foot is, therefore, an urgent issue.

Prevention of foot fissure is important in patients with diabetes, as this pathology represents one of the risk factors for developing foot ulcer.⁷ Fissures are generally considered to develop with dry skin resulting from decreased perspiration associated with autonomic neuropathy.

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The xerosis assessment scale,^{8–11} overall cutaneous score,^{9,10} dryness area severity index score,¹² transepidermal water loss,¹³ and skin hydration¹³ have been used as indicators of dry skin. Skin hydration is affected by the amount of moisture in the stratum corneum, and can be used to quantitatively assess the severity of dry skin. However, the optimal cutoff for skin hydration to avoid fissure is unknown. The indications in terms of skin hydration for the application of moisturizer to address dry skin are thus unclear.

Skin hydration is also affected by age and climate. In addition, the presence of deep fissures correlates with angiopathy,¹⁴ although the relationship between angiopathy and skin hydration is unknown. Effective care can be established if factors associated with low skin hydration in patients with diabetes can be elucidated.

The purpose of this study was to investigate the cutoff point of skin hydration with fissure and factors associated with low skin hydration in patients with diabetes. Our findings are expected to contribute to preventive care for foot fissure in patients with diabetes.

Subjects and methods

Subjects

This study was designed as a cross-sectional chart review. Subjects were patients with diabetes who visited the diabetic foot clinic at a university hospital in Tokyo and evaluated skin hydration on the heel between April 2008 and March 2015. Patients with ulcers or foot defects due to amputation were excluded. When visiting the diabetic foot clinic more than twice in this period, data from the first visit were used for analysis. The diagnosis of diabetes mellitus was based on the Japan Diabetes Society criteria.¹⁵

Investigation items

Data about fissures, skin hydration on the heel, age, sex, type of diabetes, duration of diabetes, concentration of glycosylated hemoglobin, coefficient of variation of R–R intervals (CVRR), ankle–brachial index (ABI), toe–brachial index (TBI), monofilament test, and tinea pedis were collected from the medical charts.

Fissure was defined as any linear gap or slit in the skin surface,¹⁶ and was judged by a certificated diabetic care nurse and a nursing researcher specializing in wound care. Only the fissures on the heel were used for analysis because the relationship between presence of fissures and skin hydration on the heel was investigated.

Skin hydration on the heel was measured using a moisture checker (TSMY-707S; Scalar Corporation, Tokyo, Japan).

The TSMY-707S is a portable device for hand-held use, and can estimate the moisture content to a depth of several dozen microns based on the capacitance in the area in contact with the sensor. Range of reading and accuracy are 0%–99.9% and $\pm 0.2\%$, respectively. Measurements were made three times in the center of the heel pad, and the median was calculated. Skin hydration on either the fissure side or the side with lower skin hydration between the right foot and the left foot was used for analysis. The heel was chosen as the site of measurement because this is a site at which fissures commonly develop.

Autonomic neuropathy was assessed by CVRR. To measure variations in CVRR, a device measuring blood pressure pulse wave (form PWV/ABI BP-203RPE II; Omron Colin, Tokyo, Japan) was used. The definition of abnormal CVRR was based on in-hospital criteria: age 20–29 years, <2.46 ; 30–39 years, <2.13 ; 40–49 years, <1.66 ; 50–59 years, <1.41 ; 60–69 years, <1.25 ; and ≥ 70 years, <1.14 . Angiopathy was assessed by ABI and TBI measured in a supine position after >15 min of rest using the same device employed for measurement of CVRR. If ABI was ≤ 0.9 , or if ABI was >1.4 and TBI was <0.7 , the patient was judged as showing angiopathy.¹⁷

Regarding the Semmes–Weinstein monofilament test, plantar aspects of the first toe, first metatarsal head, and fifth metatarsal head were tested on both the feet using the 10 g Semmes–Weinstein monofilament. The monofilament test was repeated twice at the same site, in addition to at least one “mock” monofilament application. Sensation was determined to be normal at each site if the patient correctly answered two out of three applications.

Tinea pedis was judged from the microscopic findings of scales and hyperkeratosis on the sole by a certificated diabetic care nurse and a nursing researcher specializing in wound care. Subjects receiving treatment for tinea pedis were also judged positively for the presence of tinea pedis.

Statistical analysis

Continuous data are expressed as mean \pm SD. Differences in skin hydration between heels with and without fissure were analyzed using the independent *t*-test, and cutoffs for skin hydration with fissure were investigated using receiver operating characteristic analysis. Based on the determined cutoff for skin hydration, relationships between lower skin hydration and each parameter were analyzed using the *t*-test and chi-squared test, and factors associated with lower skin hydration were analyzed using logistic regression analysis.

Statistical analysis was performed using IBM SPSS Statistics version 20 (IBM Corporation, Armonk, NY, USA). The level of statistical significance was $p=0.05$.

Ethical consideration

This study was approved by the ethics committee at the Graduate School of Medicine and Faculty of Medicine, University of Tokyo (No. 3078-(2)). This protocol was described in the website of the University of Tokyo and displayed on posters throughout the hospital, and subjects were provided with the opportunity to opt out.

Results

Subjects

A total of 693 subjects were included in this study. Mean±SD age was 66.8±10.8 years, and 57.0% were male (Table 1). Autonomic neuropathy was seen in 56 subjects (8.1%), and angiopathy was evident in 46 (6.7%). Fissures on the heels were observed in 72 subjects (10.4%).

Skin hydration cutoff for fissure

The *t*-test revealed that skin hydration was significantly lower in heels with fissure than in heels without (14.6%±6.3% vs. 19.1%±6.0%, $p<0.001$).

Results of receiver operating characteristic analysis of skin hydration according to the presence of fissure showed an area under the curve of 0.717 ($p<0.001$; Figure 1). Twenty percent was selected as the cutoff, offering sensitivity of 0.478 and specificity of 0.819, because higher specificity was considered preferable for fissure prevention (Table 2).

Table 1 Characteristics of subjects

Variables	N=693
Age (years)	66.8±10.8
Sex	
Male	395 (57.0)
Female	298 (43.0)
Type of diabetes	
Type 1	30 (4.3)
Type 2	635 (91.8)
Others	28 (3.9)
Duration of diabetes (years) ^a	14.3±9.9
HbA1c (%) ^b	7.2±1.1
Autonomic neuropathy ^c	
Yes	56 (8.1)
No	635 (91.9)
Angiopathy ^d	
Yes	46 (6.7)
No	640 (93.3)
Monofilament test ^e	
Abnormal	147 (21.2)
Normal	545 (78.8)

Notes: n (%), mean±SD. Some data were missing. ^an=689; ^bn=630; ^cdecreased ECG R-R interval variability; ^dankle-brachial index ≤0.9, or ankle-brachial index >1.4 and toe-brachial index <0.7 ^en=692.

Abbreviations: ECG, electrocardiogram; HbA1c, glycated hemoglobin.

Factors associated with skin hydration <20.0%

Various factors between subjects with <20.0% of skin hydration and subjects with ≥20.0% of skin hydration were compared. Univariate analysis revealed that male sex and tinea pedis were significantly more common among subjects with skin hydration <20.0% (63.1% and 67.4%, respectively) than among those with skin hydration ≥20.0% (49.4%, $p<0.001$ and 54.5%, $p=0.001$, respectively), as shown in Table 3. In addition, room temperature when measuring skin hydration was significantly lower among subjects with skin hydration <20.0% (24.8°C±2.0°C) than among those with skin hydration ≥20.0% (25.2°C±1.7°C, $p=0.005$).

Logistic regression analysis showed correlations between three factors (male sex, tinea pedis, and room temperature) and skin hydration <20.0% (odds ratio [OR] 1.587, 95% CI 1.157–2.178, $p=0.004$; OR 1.548, 95% CI 1.122–2.135, $p=0.005$; and OR 0.900, 95% CI 0.823–0.985, $p=0.021$, respectively), even though age was entered as an adjusting factor (Table 4).

Discussion

The present study is the first to seek to clarify a suitable cutoff for skin hydration in patients with diabetes at risk of heel fissure, revealing a value of 20%. Furthermore, male sex, tinea pedis, and room temperature were, for the first time, identified as factors associated with skin hydration <20%. These findings may be important in designing preventive care for patients at risk of fissures.

Factors associated with skin hydration <20.0%

One of the factors associated with skin hydration <20.0% was tinea pedis. To the best of our knowledge, a relationship between tinea pedis and skin hydration has not been previously described. Dry skin is a symptom of tinea pedis, and fissures can develop from dry skin. Direct microscopy was not conducted for the diagnosis of tinea pedis in this study. Further research using direct microscopy is thus needed to validate the relationship between lower skin hydration and tinea pedis.

Male sex and lower room temperature were also found as factors associated with skin hydration <20.0%. To the best of our knowledge, the relationships between male sex or room temperature and skin hydration have not yet been clarified. Confounding factors such as application of moisturizer and season might thus influence the results of studies.

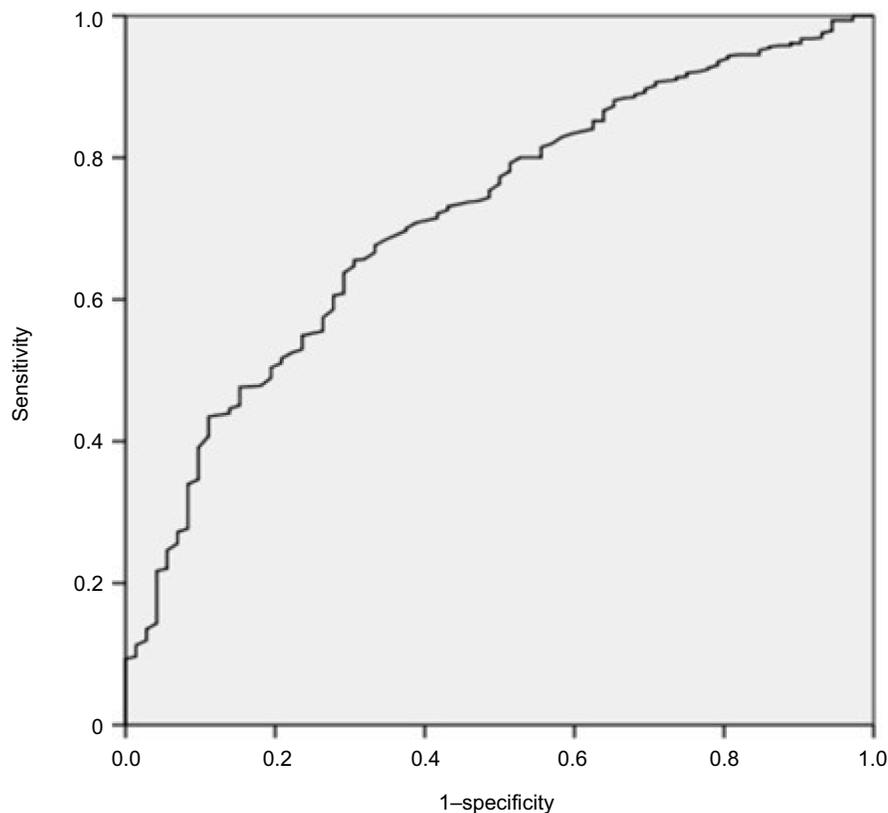


Figure 1 ROC analysis of skin hydration according to the presence of fissure.

Note: AUC=0.717; $p<0.001$.

Abbreviations: AUC, area under the curve; ROC, receiver operating characteristic.

Table 2 Sensitivity and specificity of skin hydration for the presence of fissure

Skin hydration (%)	Sensitivity	Specificity
15.0	0.731	0.569
16.0	0.670	0.667
17.0	0.628	0.708
18.0	0.591	0.722
19.0	0.530	0.764
20.0	0.478	0.819
21.0	0.425	0.889
22.0	0.351	0.903
23.0	0.290	0.917
24.0	0.230	0.944
25.0	0.172	0.958

On the other hand, autonomic neuropathy was not associated with skin hydration $<20.0\%$, but fissures are generally considered to develop in dry skin due to decreased perspiration associated with autonomic neuropathy.⁷ Additionally, sweat gland function was not evaluated in the present study, though the devices which can detect nerve damage by evaluating sweat gland function might be useful. This might

represent a limitation of the present study, in which autonomic neuropathy was judged based solely on CVRR. In addition, angiopathy was not a factor associated with skin hydration $<20.0\%$, but has been identified as a factor associated with deep fissure in patients with diabetes.¹⁴ This result might suggest that angiopathy influences deep tissues only, not superficial tissues such as the stratum corneum.

Limitations of the study

Some limitations of this study need to be considered. Lower skin hydration cannot be confirmed as a cause of fissure in this study, given the cross-sectional design. Application of moisturizer is recommended for dry skin by several guidelines, but a longitudinal study was not ethically feasible. However, lower skin hydration seems unlikely to result from fissures, because skin hydration was not measured at sites located immediately above the fissure; so, this potential flaw should have little impact on the novelty of these findings. The data about the use of moisture creams and other agents were not unavailable. Therefore, this result could not exclude the effect of this factor.

Table 3 Factors associated with lower skin hydration (univariate)

Variables	Skin hydration <20%, n=383	Skin hydration ≥20%, n=310	p-value
Age (years)	66.8±10.4	66.9±11.4	0.929 ^a
Sex			<0.001 ^b
Male	242 (63.1)	153 (49.4)	
Female	141 (36.8)	157 (50.6)	
Duration of diabetes (years)	13.9±9.9	14.7±9.9	0.301 ^a
HbA1c (%)	7.2±1.2	7.2±1.1	0.508 ^a
Autonomic neuropathy ^c			0.788 ^b
Yes	30 (7.9)	26 (8.4)	
No	352 (92.1)	283 (91.6)	
Angiopathy ^d			0.873 ^b
Yes	26 (6.8)	20 (6.5)	
No	354 (93.2)	286 (93.5)	
Monofilament test			0.153 ^b
Abnormal	89 (10.2)	58 (18.8)	
Normal	294 (76.8)	251 (81.2)	
Tinea pedis			0.001 ^b
Yes	258 (67.4)	169 (54.5)	
No	125 (32.6)	141 (45.5)	
Room temperature (°C)	24.8±2.0	25.2±1.7	0.005 ^a
Room humidity (%)	37.1±11.9	38.7±11.9	0.100 ^a

Notes: n (%), mean±SD. Some data are missing. ^at-test; ^bchi-squared test; ^cdecreased ECG R–R interval variability; ^dankle–brachial index ≤0.9, or ankle–brachial index >1.4 and toe–brachial index <0.7.

Abbreviations: ECG, electrocardiogram; HbA1c, glycated hemoglobin.

Table 4 Factors associated with lower skin hydration (multivariate)

Variables	Odds ratio	95% CI		p-value
		Lower	Upper	
Age (years)	1.000	0.986	1.015	0.952
Male sex	1.587	1.157	2.178	0.004
Tinea pedis	1.548	1.122	2.135	0.008
Room temperature	0.900	0.823	0.985	0.021

Notes: Logistic regression analysis. Forced entry method. Hosmer–Lemeshow analysis: $\chi^2=2.887$; $p=0.941$.

Relevance to clinical practice

Use of moisturizers is recommended to lubricate dry skin for patients with diabetes.¹⁸ Topical moisturizers are beneficial for managing dry skin,¹⁹ with many studies showing demonstrable improvements in skin condition compared to use of a moisturizer with placebo base cream, although no conclusive recommendations were reached in a systematic review.²⁰ Although no particular ingredient or formulation of moisturizer could be recommended, this study revealed that application of moisturizer for prevention of fissure in patients with diabetes should be followed for a suggested skin hydration of 20.0%.

Conclusion

To prevent the heel fissure, moisturizing care at a skin hydration of <20% appears useful as a guide. Moisturizing care for preventing fissures may be particularly worthwhile for

men and in cold environments. For skin hydration <20%, to prevent fissures, not only moisturizing care but also the possibility of treatment for tinea pedis should be considered.

Disclosure

The authors report no conflicts of interest in this work.

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