

Reliability of Infrared Thermography Images in the Analysis of the Plantar Surface Temperature in Diabetes Mellitus

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ABSTRACT

Objective: The purpose of this study was to evaluate the intraexaminer and interexaminer reliability of image assessment of infrared thermography of the plantar surface of people with diabetes mellitus.

Methods: Fifty-one participants with diabetes were included. The interexaminer reliability (test) consisted of measuring the temperature of the plantar surface by 2 evaluators who separately performed the analysis of thermographic images. The intraexaminer reliability (retest) consisted of the reevaluation of the images by a single evaluator 10 days after the first analysis.

Results: The analysis of intrareliability and interreliability indicated excellent levels of correlation (intraclass correlation coefficient >0.75 , 95% confidence interval >0.70) in the plantar surface points analyzed.

Conclusion: Infrared thermography image evaluation identified intrareliability and interreliability for temperature analysis of the plantar surface of people with diabetes mellitus. However, further studies need to be conducted to assess validity and its application in health care. (J Chiropr Med 2018;17:30-35)

Key Indexing Terms: *Body Temperature; Diabetic Foot; Lower Limbs; Reproducibility of Results*

INTRODUCTION

Infrared thermography is based on the emission of infrared radiation from a particular object or region as seen through a thermographic camera.¹⁻³ This instrument enables the detection of the heat distribution on the surface and at the same time allows the measurement of peripheral temperature.²⁻⁴ After capturing the image, one can obtain a record of temperature gradients in colorful hues and enable the computational analysis of the quantification and interpretation of the image.³ This method allows the measurement

of the average temperature, the temperature difference and thermal recovery rate.⁵ Researchers interested in investigating the use of infrared thermography in health care have reported the benefit of the method in the evaluation of musculoskeletal disorders, diabetic neuropathy, and vasculopathy.^{1,3,4,6-10} Other studies have been conducted to test the use of thermography in detecting problems related to gynecology and obstetrics, neonatology, cardiology, nephrology, neurology, and dermatology.^{4,6,7,11-13} This method has been used to diagnose disease and monitor various clinical conditions.^{1,4,10} The detection of small changes in temperature in specific regions may suggest corresponding changes in the physiology, which contributes to the screening, diagnosis, and treatment of various diseases.^{1,6-10}

Body temperature, mediated by sensory innervation and peripheral circulation, is directly influenced by room temperature.¹¹ In the presence of local lesions, impairment occurs in perception and thermal regulation, which promotes metabolic and physiological changes in an organism.^{11,12} In this sense, a person with diabetes mellitus presents with damage in peripheral nerves and blood vessels and has a reduction in lower limb temperature.^{12,13} This can be explained by the involvement of regulatory mechanisms: neurovegetative and motor mechanisms of blood vessels, resulting in the reduction of vasomotor function and lifting or lowering the temperature of the feet.¹⁴ Acquired

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neuropathy exposes the individual to a higher probability of complications in different body regions, especially in the extremities, and increased risk of developing skin lesions, resulting in high costs of hospitalization and medical expenses.¹⁵

Infrared thermography, as a noninvasive method, measures changes in the peripheral body temperature,^{8,10,16} maps body temperature,¹¹ and tracks changes that decrease or increase body temperature.^{1,2,3,8} However, because it is a new methodology in health care, its applicability and effectiveness as a method of evaluation need further testing.⁴ Few studies have reported the intrarater and interrater reliability of this instrument.

Therefore, the purpose of this study was to assess the intrarater and interrater reliability of infrared thermography in the analysis of the plantar surface temperature of people with diabetes mellitus.

METHODS

This was a cross-sectional study. A test–retest design was used to evaluate the intraexaminer and interexaminer reliability of the temperature measured by the infrared thermography. This study was part of a larger project titled “The Use of Reflexology Feet as Treatment for Patients With Diabetes Mellitus.” This was approved by the Ethics Committee of the Federal University of Alfenas, Minas Gerais, Brazil (CAAE: 07183512.1.00005142).

Population and Sample

Fifty-one participants with type 2 diabetes mellitus from 2 primary health care units participated. The following were inclusion criteria: diagnosis of the disease for at least 5 years, minimum age of 18 years old, both sexes, infrequent medical monitoring for diabetes control in 2 primary health care units. Exclusion criteria were presence of ulcers, presence of amputations of the lower limbs, uncontrolled hypertension, thrombosis, presence of burns, and fever.

The following guidelines were given to the participants before the examination: Avoid alcohol 24 hours before the examination, caffeine and cigarettes 2 hours before the examination, vigorous sports activities on examination day, and the use of lotions or powders on your feet on examination day.^{17,18} All participants gave consent to participate.

Photographic Record

For thermographic recording, the participants were positioned supine with bare feet and held that position for 15 minutes. This amount of time was used because it is the time required for the body heat to come into balance with the environment and produce stable recordings.¹⁹ During this period, participants avoided touching their feet, and all electronics that could compromise the evaluation were

removed. The testing environment was thermally controlled at a constant temperature of 23°C.^{17,20} To obtain stable interpretations of plantar temperature and to prevent that the temperature of other parts of the body interfering on the photographic record, the feet were thermally insulated by a uniform backdrop.¹⁸ This uniform backdrop consisted in a box with 2 openings for the feet.

All participants had their feet photographed with an infrared thermal camera (FLIR, model E60, Wilsonville, Oregon), with emissivity set to 0.98.⁴ According to the manufacturer, this device enables measurement of temperatures ranging from –120°C to 650°C. The equipment was positioned on a tripod at a standardized height of 0.95 m from the ground and at a distance of 0.98 m from the participants’ feet, which provided a picture without distortion. All photographic records were performed by a single observer who was familiar with the camera.

Reliability of Infrared Thermography

To assess intraexaminer reliability, a single evaluator analyzed thermographic images of the 18 points shown in Figures 1A and 1B on 2 different occasions. Respecting an interval of time for the data storage was not possible. The first evaluation was conducted on the day the images were captured by the thermographic camera, and the second evaluation was conducted after 10 days. The Quick Report Software Version 1.1 (FLIR Systems) that was provided by the camera’s manufacturer was used for these analyses.

To assess interrater reliability, the image analysis was performed by 2 different evaluators in different locations and with different computers. Therefore, there was no exchange of information between examiners that could interfere with the assessments. Results were recorded separately to avoid the comparison of data during the analysis.

Statistical Analysis

We calculated sample size using G*Power Software Version 3.1.7 (Christian-Albrechts-Universität Kiel, Kiel, Germany) that estimated the need for 12 participants for a power of 0.80. The intraexaminer result concordance was analyzed by means of the intraclass correlation coefficient (ICC), assessing the measure consistency by each rater in 2 evaluations, whereas the interexaminer result concordance was analyzed by means of ICC, considering the between-rater concordance at the 2 time intervals for 1 measure assessed. The interpretation of the ICC was according to Fleiss (<0.40, poor correlation; 0.40–0.75, moderate correlation; >0.75, excellent correlation).²¹ The 95% confidence interval (CI) was calculated, with values >0.70 being considered excellent.^{22,23} The calculation of the standard error of measurement (SEM) was performed using the following formula: $SEM = SD \times \sqrt{(1 - ICC)}$, wherein SD corresponds to the standard deviation.²⁴ Minimum detectable change (MDC) was calculated with the following formula: $MDC = z \text{ score level of confidence} \times SD$

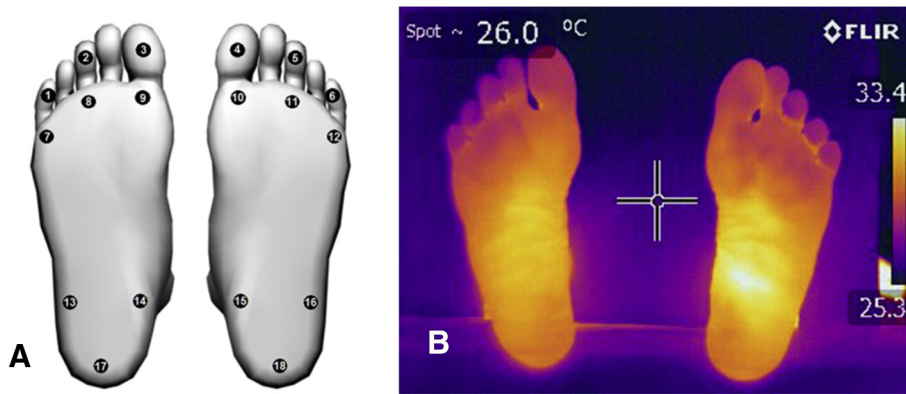


Fig 1. (A) The 18 points used for the study. (B) A sample thermographic image.

baseline $\times \sqrt{(2[1 - \text{test-retest}])}$. In this study, CI = 95%; $z = 1.96$.²³ Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) Version 19.0 (IBM Corp., Armonk, New York). A significance level (α) of .05 was used for all tests.

RESULTS

The sample consisted of 51 people with diabetes mellitus (mean time since diagnosis of diabetes 10 years [SD = 6, 16]), with a mean age of 61.5 years (SD = 9.8), mean weight of 75.11 kg (SD = 13.05), mean height of 1.63 m (SD = 0.2), and 63.5% women and 36.5% men. Other patient characteristics are described in Table 1.

Reliability of Infrared Thermography

The assessment of the 18 points indicated excellent correlation in both the intraexaminer and interexaminer analysis

Table 1. Patient Characteristics (N = 51)

Patient Characteristics	Yes (%)	No (%)	
Smoker	15.55	84.44	
Hypertension	82.22	17.77	
Practices physical activity	33.34	66.66	
Feet assessment by a health professional	20.00	80.00	
Counseling on self-care for the feet	35.56	64.44	
Risk rating analysis	Low 24.44	Moderate 15.55	High 4.44
Glycemic control	Oral hypoglycemic 91.11	Insulin 8.88	

Rows may not equal 100% due to rounding.

(ICC > 0.75; 95% CI > 0.70; $P < .01$). This analysis may be due to the results obtained and the MDC, which represents good stability through repeated testing.²³ All values obtained in the intra-analyses and interanalyses are described in Table 2.

DISCUSSION

The results of this study indicate that infrared thermography, when used by the same person at different times and by another examiner, is a reliable method for assessing images of plantar surface temperature of people with diabetes mellitus. The MDC and the minimum clinically important changes it aims to measure include the effects and cost of treatments, clinical relevance, and tolerability of treatment choices.²⁵ In the present study, the interpretation of MDC indicates that the results are clinically significant because of the low values identified.^{23,26}

These findings may inform the selection of interventions or contribute to reduction of financial expenses with the clinical evaluation process.²³ Some studies have used infrared thermography as an evaluation method^{19,27,28} and relate its reliability and validation to certain clinical conditions.^{5,28,29}

For analysis of foot temperature of people diagnosed with diabetes mellitus, only 1 study investigated the thermal recovery of the feet after cooling was identified. Another study pointed out that thermography was reliable, suitable for the evaluation of peripheral circulation, and could be used to monitor the treatment of people with diabetes mellitus.¹⁹ Thermography has been used to study the variation of plantar temperatures in patients with diabetes and those without diabetes²⁷ and for the early evaluation of neuropathy. However, not all studies perform reliability analyses or instrument validation.¹³ Thermographic imaging could possibly be used to assess infections in people with diabetic foot, facilitate early evaluation of the feet, and observe for signs of infection.^{16,30} Moreover, it can be an additional tool for the diagnosis of diabetic neuropathy and

Table 2. Analysis of Intraexaminer and Interexaminer Reliability of Infrared Thermography

Points	Temperature (°C)			Intraexaminer					Interexaminer				
	1st Examiner	2nd Examiner	Retest 1st Examiner	ICC	Level	SEM	95% CI	MDD	ICC	Level	SEM	95% CI	MDD
1	29.40 ± 3.41	29.35 ± 3.43	29.39 ± 3.42	1.00	Excellent	0.00	1.00-1.00	0.00	0.99	Excellent	0.10	0.99-0.99	0.30
2	29.47 ± 3.70	29.46 ± 3.76	29.39 ± 3.66	0.99	Excellent	0.23	0.99-0.99	0.64	0.99	Excellent	0.11	0.99-1.00	0.33
3	30.21 ± 3.38	30.21 ± 3.39	30.20 ± 3.38	1.00	Excellent	0.00	1.00-1.00	0.00	0.99	Excellent	0.10	0.99-0.99	0.29
4	30.03 ± 3.33	30.03 ± 3.37	30.03 ± 3.33	1.00	Excellent	0.00	1.00-1.00	0.00	0.99	Excellent	0.10	0.99-1.00	0.29
5	29.38 ± 3.70	29.32 ± 3.73	29.37 ± 3.70	1.00	Excellent	0.00	1.00-1.00	0.00	0.99	Excellent	0.11	0.99-1.00	0.32
6	29.51 ± 3.36	29.46 ± 3.37	29.51 ± 3.36	1.00	Excellent	0.00	1.00-1.00	0.00	0.99	Excellent	0.10	0.99-1.00	0.29
7	29.90 ± 3.36	30.20 ± 2.88	29.90 ± 3.02	1.00	Excellent	0.00	1.00-1.00	0.00	0.94	Excellent	0.73	0.89-0.96	2.05
8	30.55 ± 2.83	30.55 ± 2.81	30.56 ± 2.84	1.00	Excellent	0.00	1.00-1.00	0.00	0.99	Excellent	0.15	0.99-0.99	0.43
9	30.83 ± 2.71	30.88 ± 2.71	30.81 ± 2.71	1.00	Excellent	0.00	1.00-1.00	0.00	0.99	Excellent	0.08	0.99-0.99	0.23
10	30.73 ± 2.70	30.78 ± 2.70	30.74 ± 2.69	1.00	Excellent	0.00	1.00-1.00	0.00	0.99	Excellent	0.12	0.99-0.99	0.33
11	30.55 ± 2.74	30.56 ± 2.73	30.55 ± 2.75	1.00	Excellent	0.00	1.00-1.00	0.00	0.99	Excellent	0.08	0.99-0.99	0.24
12	30.22 ± 2.71	30.28 ± 2.77	30.22 ± 2.70	1.00	Excellent	0.00	1.00-1.00	0.00	0.99	Excellent	0.15	0.99-0.99	0.42
13	30.40 ± 2.41	30.53 ± 2.44	30.39 ± 2.39	1.00	Excellent	0.00	1.00-1.00	0.00	0.98	Excellent	0.31	0.97-0.99	0.88
14	30.56 ± 2.32	31.45 ± 1.82	30.56 ± 2.32	1.00	Excellent	0.00	1.00-1.00	0.00	0.94	Excellent	0.53	0.90-0.96	1.49
15	30.38 ± 2.47	31.30 ± 1.82	30.34 ± 2.45	0.99	Excellent	0.15	0.99-0.99	0.43	0.94	Excellent	0.58	0.89-0.96	1.63
16	30.29 ± 2.49	30.38 ± 2.36	30.29 ± 2.48	1.00	Excellent	0.00	1.00-1.00	0.00	0.98	Excellent	0.34	0.96-0.98	0.95
17	29.97 ± 2.58	30.48 ± 2.57	29.96 ± 2.57	1.00	Excellent	0.00	1.00-1.00	0.00	0.99	Excellent	0.24	0.98-0.99	0.67
18	29.80 ± 2.65	30.31 ± 2.56	29.81 ± 2.63	1.00	Excellent	0.00	1.00-1.00	0.00	0.99	Excellent	0.22	0.98-0.99	0.61

The table presents the result consistency for each rater. The mean as well as standard deviation of the values obtained in each assessment session and by each rater are presented, in addition to the intraclass correlation coefficient (ICC³), confidence interval (CI), standard error of measurement (SEM), and minimal detectable change (MDC).^{17,18}

several other pathologic conditions.^{13,14} Infrared thermography may be a reliable instrument for measuring signs of temperature increase or decrease as well as for signal evaluation of inflammation.^{5,29,31}

For reliability analysis and validation of infrared thermography, it is important to use adequate instruments.³² Professionals responsible for thermographic analyses should be properly trained, and recommendations issued by the literature should be followed with the utmost rigor possible.³²⁻³⁴ Further requirements include the presence of a thermally controlled environment, the proper preparation and orientation of the person who will undergo analysis, and the standardization of the technique with respect to the intervals of analysis, and completion of independent instruments by investigators.^{13,17,20}

Limitations

We did not control for the menstrual cycle period with female volunteers, and this may have influenced the findings. It is known that there is influence of menstruation on the surface skin temperature. Infrared thermography has yet to be reported as a valid instrument to detect the surface temperature of the skin on the feet of people with type 2 diabetes mellitus. This study did not correlate results with clinical data and physical examination or other tests; thus, clinical relevance has yet to be proven.

CONCLUSION

According to the results of this study, intraexaminer and interexaminer reliability was good for the analysis of infrared

thermography images of the plantar surface temperature of people with diabetes mellitus.

FUNDING SOURCES AND CONFLICTS OF INTEREST

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Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): N.C.M.S., H.A.C., L.C.C., E.C.L.C., L.O.R., D.H.I.

Practical Applications

- The analysis of intrareliability and interreliability indicated excellent levels of correlation (ICC >0.75, 95% CI >0.70) in the plantar surface points analyzed.
- Further studies should be conducted to ensure validity and greater reliability of the method and its application in health care.

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