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Anthropometric Profile and Diabetic Foot Risk: A Cross-Sectional Study Using Thermography

Eduardo B. Neves, António J. Almeida, Claudio Rosa, José Vilaça-Alves, Victor M. Reis and Romeu Mendes

Abstract— **Diabetes is one of the greatest todays public health problems with enormous social and economic implications for society. Diabetic foot disorders represent a substantial economic burden with detrimental effects on quality of life with special impairment in physical domain. Early detection strategies of these complications should be implemented in order to avoid possible wounds, ulcerations and amputations. This work can be characterized as a cross-sectional study with an analytical approach. It involved 44 volunteers of both genders (22 women and 22 men; 66.70 ± 6.26 years of age) with type 2 diabetes (diagnosed at 11.84 ± 8.22 years), selected among the candidates to *Diabetes em Movimento*® (a community-based exercise program for patients with type 2 diabetes developed in the city of Vila Real, Portugal). Foot plantar thermal images were acquired through a high-resolution infrared camera (*FLIR Systems Inc. Model* SC2000; 320 x 240 pixels). Three regions of interest (ROI) were defined for evaluation: first finger, fifth finger and the heel. From the three pairs of ROIs evaluated, the higher temperature asymmetry was selected for diabetic foot risk analysis. The results showed the existence of a positive and significant association between BMI and fat mass with asymmetries in feet temperature. Three subjects with diabetes-related foot complications (ROIs higher temperature asymmetry ≥ 2.20 ºC) were identified in the sample. All participants with detected diabetes-related foot complications were obese (BMI ≥ 30 kg/m^2) with high levels of body fat (≥ 45%). It can be concluded that exist a positive association either of BMI (r=0.399, p=0.007) either of body fat percentage (r=0.432, p=0.003), with diabetic foot risk in patients with type 2 diabetes.**

I. Introduction

Diabetes is one of the greatest todays public health problems with enormous social and economic implications for society [1, 2]. Diabetic foot disorders represent a substantial economic burden with detrimental effects on quality of life with special impairment in physical domain [3]. Early detection strategies of these complications should be implemented in order to avoid possible wounds, ulcerations and amputations [4]. The evaluation of factors associated with increased risk of diabetic foot is also important [5].

Thermography has been used as a diagnostic tool for various disorders: cancer diagnosis [6], carpal tunnel syndrome[7], complex regional pain syndrome[8], muscle damage diagnosis [9, 10], and evaluation of muscle recovery[11], and also to evaluate diabetic foot risk and diabetes-related foot complications already established [12-14].

Authors have reported that obesity is a major risk factor for the development of the diabetic foot[15, 16]. The body mass index (calculated from the body mass and height) and the percentage of fat are among the obesity indicators most commonly used in the literature[17, 18]. In this sense, this study aimed to analyze the association between the anthropometric profile (body mass, body height, body mass index and body fat) and diabetic foot risk in patients with type 2 diabetes, assessed through digital infrared thermal imaging technique.

II. Method

A. Study design and Sample

This work can be characterized as a cross-sectional study with an analytical approach. It involved 44 volunteers of both genders (22 women and 22 men; 66.70 ± 6.26 years of age) with type 2 diabetes (diagnosed at 11.84 ± 8.22 years), selected among the candidates to *Diabetes em Movimento*® (a community-based exercise program for patients with type 2 diabetes developed in the city of Vila Real, Portugal [19]) according with the following inclusion criteria: type 2 diabetes diagnosed at least one year; without active foot wounds or ulcers; community-dwelling; non-smokers; without major cardiovascular, pulmonary, musculoskeletal, renal, and neurological disease; and signed informed consent. The experimental procedures involving human subjects described in this paper were approved by the Institutional Review Board.

B. Instrumentation and Data Acquisition

Body mass and body fat were assessed by bioelectrical impedance analysis technique (*Tanita, BC-418 MA*) on fasting state conditions. Body height was measured with a stadiometer (*SECA, 220*) with a graduation of 0.5 cm.

Foot plantar thermal images were acquired through a high-resolution infrared camera (*FLIR Systems Inc. Model* SC2000; 320 x 240 pixels). This instrument measures temperatures ranging from -20 °C to + 120 ºC with sensitivity

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to detect differences of less than 0.1 °C, and accuracy of ± 1 °C of the absolute temperature.

In order to monitor the laboratory's temperature (20 ± 1 ºC) and humidity (55 %), a digital thermohygrometer was used.

C. Data Analysis

Body mass and body height were used to calculate body mass index (BMI).

Thermal images were analyzed using the software *ThermaCam™ Researcher Pro 2.9 (FLIR Systems Inc.)*. Three regions of interest (ROI) were defined for evaluation: first finger, fifth finger and the heel, as illustrated in Figure 1. The average of ROI temperature was considered for the analyses. For each pair of ROI (e.g. AR01 and AR02 in Figure 1) skin temperature difference (asymmetry) was calculated for each volunteer. From the three pairs of ROIs evaluated, the higher temperature asymmetry was selected for diabetic foot risk analysis. A cut-off difference of 2.2 ºC was used to detect diabetes-related foot complications [20].

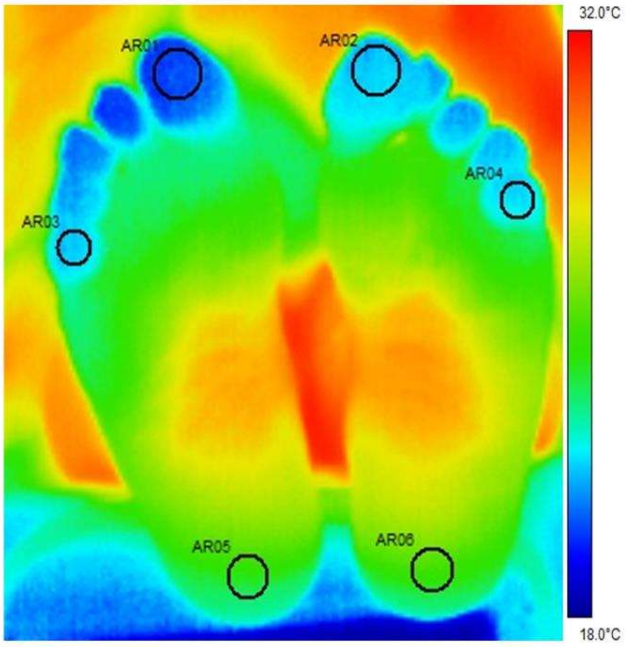

Figure 1. Illustration of plantar foot thermal images analysis protocol. The circles indicate the regions of interest (ROI).

D. Statistical Analysis

Pearson's correlations were used to evaluate the association between anthropometric profile variables (body mass, body height, BMI and body fat) and the higher temperature asymmetry (among the three pairs of ROIs evaluated). The statistical analyses were carried out with software *Statistical Package for Social Sciences* (*IBM SPSS, version 21.0*). The statistical significance level was defined as $p < 0.05$.

III. Results

Anthropometric profile variables and ROIs temperature values are presented in Table I. All volunteers were right-handed.

TABLE I. ANTHROPOMETRIC AND THERMAL VARIABLES (N=44)

Variables	Average	SD
Body mass (kg)	77.95	10.94
Body height (m)	1.62	0.09
Body mass index (kg/m^2)	29.66	3.52
Body fat (%)	36.74	8.04
Right first finger skin temperature (ºC)	20.82	1.89
Left first finger skin temperature (ºC)	20.45	1.79
Right fifth finger skin temperature (ºC)	21.47	2.32
Left fifth finger skin temperature (ºC)	21.01	1.85
Right heel skin temperature (ºC)	22.86	1.69
Left heel skin temperature (ºC)	22.79	1.34

SD, standard deviation.

Table II presents the Pearson´s correlation coefficients between anthropometric variables and the higher temperature asymmetry (among the three pairs of ROIs evaluated).

TABLE II. PEARSON'S CORRELATION COEFFICIENTS BETWEEN ANTHROPOMETRIC PROFILE VARIABLES AND THE HIGHER TEMPERATURE ASYMMETRY (N=44).

Variables	r	*p*
Body mass x higher temperature asymmetry	0.188	0.223
Body height x higher temperature asymmetry	-0.175	0.256
Body mass index x higher temperature asymmetry	0.399*	0.007
Body fat percentage x higher temperature asymmetry	0.432*	0.003

* statistical significance

Three subjects with risk of diabetes-related foot complications (ROIs higher temperature asymmetry ≥ 2.20 ºC) were found (Table III).

TABLE III. AGE AND ANTHROPOMETRIC PROFILE OF THE VOLUNTEERS WITH DIABETES-RELATED FOOT COMPLICATIONS.

Volunteer code	Age (years)	ROI / higher temperature asymmetry (ºC)	BMI (kg/m^2)	Body Fat (%)
6	59	fifth finger / 3.4	31.62	45.90
16	79	fifth finger / 2.2	31.69	46.40
23	58	first finger / 5.9	37.18	52.40

ROI, region of interest; BMI, body mass index.

IV. Discussion

This study applied a plantar foot thermographic analysis protocol to evaluate the association between diabetic foot risk and anthropometric profile in patients with type 2 diabetes. Volunteers presented typical age and anthropometric profile of these population: aged individuals with overweight and obesity. The results showed the existence of a positive and significant association between BMI and fat mass with asymmetries in feet temperature. These contralateral asymmetries have been used to predict diabetic foot risk and detect diabetes-related foot complications [13, 20]. Besides increasing the risk of coronary artery disease and cerebrovascular disease [21], obesity can also increase the risk of peripheral arterial disease and microvascular complications such as peripheral neuropathy predisposing for diabetes-related foot problems.

The increase in the plantar pressure among obese people (because of increased body mass) can lead to changes in bone structure and tissue, changes in posture and gait. The increase in the plantar pressure is associated with the development of ulcers which can increase the risk of amputation[22]. All participants with detected diabetes-related foot complications were obese (BMI $\geq$ 30 kg/m^2) with high levels of body fat ($\geq$ 45%). Although other risk factors has not been investigated, obesity is usually associated with physical inactivity, poor diet, high blood pressure, inadequate metabolic control, alcoholism, smoking, sensitivity commitment to plant and lack of foot care[15]. Body mass control should be a priority in these patients either for metabolic control of diabetes, either for reducing the risk of associated complications such as diabetic foot.

V. Conclusion

It can be concluded that exist a positive association either of BMI (r=0.399, p=0.007) either of body fat percentage (r=0.432, p=0.003), with diabetic foot risk in patients with type 2 diabetes.

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