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ORIGINAL ARTICLE

A comparison of thermal characteristics of the small joints of the hands between patients with rheumatoid arthritis and healthy controls

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ABSTRACT

Objectives: This study aims to investigate the thermal characteristics of the small joints of the hands between patients with rheumatoid arthritis (RA) and healthy controls.

Patients and methods: Between December 2020 and May 2021, a total of 52 RA patients (9 males, 43 females; mean age: 52.1±11.1 years; range, 38 to 68 years) who met the revised American College of Rheumatology and European League Against Rheumatism (ACR/EULAR) classification criteria and 26 healthy controls (10 males, 16 females; mean age: 51.2±8.2 years; range, 38 to 68 years) were included. Joint tenderness was evaluated using Ritchie articular index (RAI). Joint tenderness was scored from 0 to 3. Thermal data were collected from the hand regions of individuals. A FLIR T450sc microbolometer infrared thermal camera with 320×240 resolution was used for the thermography of individuals. Bilaterally proximal interphalangeal joints (1-5) and metacarpophalangeal joints (1-5) were evaluated. The mean temperature was compared between the patients and healthy controls.

Results: The mean disease duration of patients with RA was 10.4±8.9 years. The mean temperature values of the joints in the patients with a RA RAI score of 0, 1, 2, 3 were 32.43±1.59°C; 32.71±1.36°C; 33.12±1.23°C; 33.60±0.99°C, respectively. The mean temperature was 31.14±1.51°C in healthy controls. The mean temperature values of the joints in the RA patients with RAI score of 0 was higher compared to healthy controls ($p<0.05$). Patients with a Ritchie sensitivity score of 1 had a higher mean temperature compared to patients with score of 0 ($p<0.05$). In RA patients, the joints with a RAI score of 1 had higher mean temperature values than the joints with RAI score of 0 ($p<0.05$). The mean temperature values of the joints with RAI score of 2 were also higher than the joints with RAI score of 1 ($p<0.05$).

Conclusion: Our study results suggest that thermal imaging may be an objective tool for diagnosis and assessing disease activity in RA.

Keywords: Rheumatoid arthritis, small joints of the hands, thermal imaging.

Rheumatoid arthritis (RA) is a chronic inflammatory disease which typically affects small joints of the hands and feet.[1] It can cause bone and cartilage damage and disability. It does not only affect the joints, but also causes extra-articular organ damage. The complications and comorbidities of RA lead to a reduced life expectancy. Therefore, early diagnosis and control of disease activity are of utmost importance.[2-4] Composite indices based on laboratory values such as erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), and physician and patient global assessment, as well as tender joint count (TJC) and swollen joint count (SJC) are frequently used to evaluate RA disease activity. However, clinical scoring systems may show inter-reader variability.[5,6] Therefore, the use of imaging of arthritic activity with objective methods is crucial.

Thermal imaging (thermography) is a non-ionizing, non-invasive, and low-cost imaging tool which is able to detect infrared radiation produced by the surface of the body and helps objectively to evaluate the temperature over the surfaces.[7,8] Several studies have shown that thermography is effective

in directly showing the temperature, which is one of the principal findings of inflammation.[9] Infrared thermography is being used in different clinical circumstances including the diagnosis and following of breast cancer and diabetic foot disease.[10,11] Thermal imaging has also been evaluated in rheumatic diseases. Gizińska et al.[12] compared the feet of 81 RA patients with the feet of 39 healthy controls in terms of thermal characteristics and showed significant differences in the mean temperature between RA patients and healthy controls. However, there was no significant difference between the left and right sides of the foot in this study.

In the present study, we aimed to evaluate whether there were differences in the thermal characteristics of the small joints of the hands between patients with RA and healthy controls, and whether there was a difference in thermal characteristics between tender and non-tender joints in patients with RA.

PATIENTS AND METHODS

This cross-sectional study was conducted at Akdeniz University Faculty of Medicine, Department of Rheumatology between December 2020 and May 2021. A total of 52 RA patients (9 males, 43 females; mean age: 52.1±11.1 years; range, 38 to 68 years) who met the revised American College of Rheumatology and European League Against Rheumatism (ACR/EULAR) classification criteria[13] and 26 healthy controls (10 males, 16 females; mean age: 51.2±8.2 years; range, 38 to 68 years) who did not have past or present rheumatic diseases were included. Those who were febrile or had an infection at the time of the examination were excluded. In addition, patients who had comorbidities that can affect thermal images such as peripheral arterial disease and diabetes mellitus and smokers were also excluded. A written informed consent was obtained from each participant. The study protocol was approved by the Akdeniz University, Medical School, Research Ethics Committee (date: 11/11/2020, no: 860). This study was conducted in accordance with the principles of the Declaration of Helsinki.

Demographic and clinical characteristics of the patients were recorded. Tender joint count for 28 joints and SJC for 28 joints, rheumatoid factors (RFs), anti-citrullinated peptide antibodies (anti-CCP), CRP and ESR were recorded. The Ritchie articular index (RAI) that is a joint score based on tenderness was used to evaluate the joints of RA patients. The RAI is based on the summation of a several quantitative evaluations of the pain felt by the patient when the joints are exposed to pressures. In RAI, subjects' responses are scored from 0 to 3 for each joint (score 0 for no pain, score +1 for tender, score +2 for tender and winced and score +3 for tender, winced and withdrew).[14] The RAI was evaluated separately for all metacarpophalangeal (MCP) and proximal interphalangeal (PIP) joints of both hands. Disease activity was evaluated by the DAS28 score. The patients were divided according DAS28 score; high disease activity with the value of DAS28>5.1, moderate disease activity with 5.1≥DAS28>3.2, low disease activity with 3.2≥DAS28>2.6, remission with DAS28<2.6.[15] The Health Assessment Questionnaire (HAQ) was used to quality of life.

Thermal data were collected from the hand regions of individuals. A FLIR T450sc microbolometer infrared thermal camera with 320×240 resolution was used for the thermography of individuals. The distance between the camera and hands was adjusted to 0.8 meter. Video recordings were prepared as 320×240 images in PNG and MAT formats using the FLIR researcher program. All thermographic images were collected in the same examination room. All participants were instructed not to use products that could affect the thermographic measurement, such as deodorant and antiperspirant, before the thermographic data collection. Thermographic measurements were made on twenty regions of interest (ROI) corresponding to PIP (1-5) and MCP joints (1-5) of the bilaterally hands of participants and°C were recorded at each anatomical joint site.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 22.0 software (IBM Corp., Armonk, NY, USA) Continuous data were expressed in mean ± standard deviation (SD), median (min-max), while categorical data were expressed in number and frequency. The Student t-test and the Mann-Whitney U test were used to

Table 1. Demographic, clinical, and laboratory characteristics of study population

	Patient group		Control group		
	n	Mean±SD	n	Mean±SD	*p*
Age (year)		52.1±11.1		51.2±8.2	>0.05
Sex Female Male	 43 9		 16 10		
Disease duration years		10.36±8.86		NE	
Tender joint count		5.59±5.79		NE	
Swollen joint count		1.93±2.85		NE	
C-reactive protein (mg/dL)		0.95±1.27			<0.05
Rheumatoid factor (IU)		87.82±201.89			
Anti-CCP (IU)		100.45±111.85			
Erythrocyte sedimentation rate (mm/h)		19.36±12.67		7.92±5.91	<0.05
Disease Activity Score 28		3.70±1.21		NE	
Health Assessment Questionnaire		2.35±0.58		NE	

SD: Standard deviation; Anti-CCP: Anti-citrullinated peptide antibodies; NE: Not evaluated.

compare the continuous variables. Categorical data were compared using the chi-square test. A *p* value of <0.05 was considered statistically significant.

RESULTS

In this study, 52 patients with RA and 26 healthy controls were included. The mean disease duration of patients with RA was 10.36±8.86 years. The characteristics of patients and healthy controls are shown in Table 1. Of the patients, 49 were receiving conventional synthetic disease-modifying antirheumatic drugs (csDMARDs). Eleven out of 49 patients were also on biological DMARDs (bDMARDs), 28 patients were also on glucocorticoids, whereas five patients were on glucocorticoids

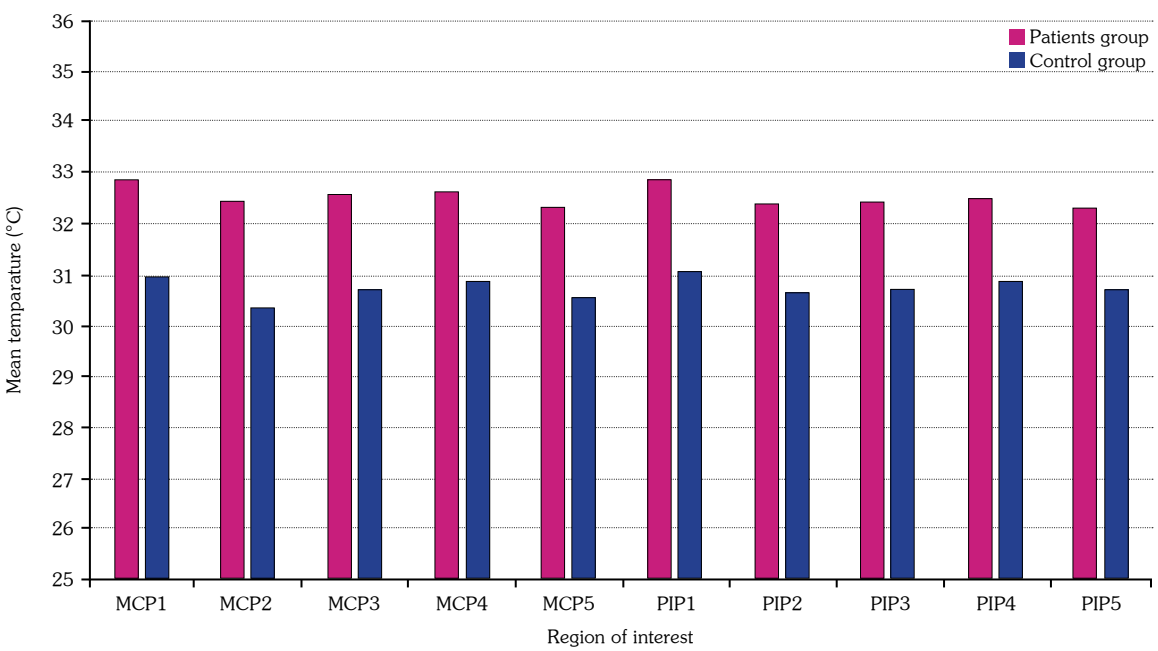

Figure 1. The mean temperatures for the right hand.
MCP: Metacarpophalangeal; PIP: Proximal interphalangeal.

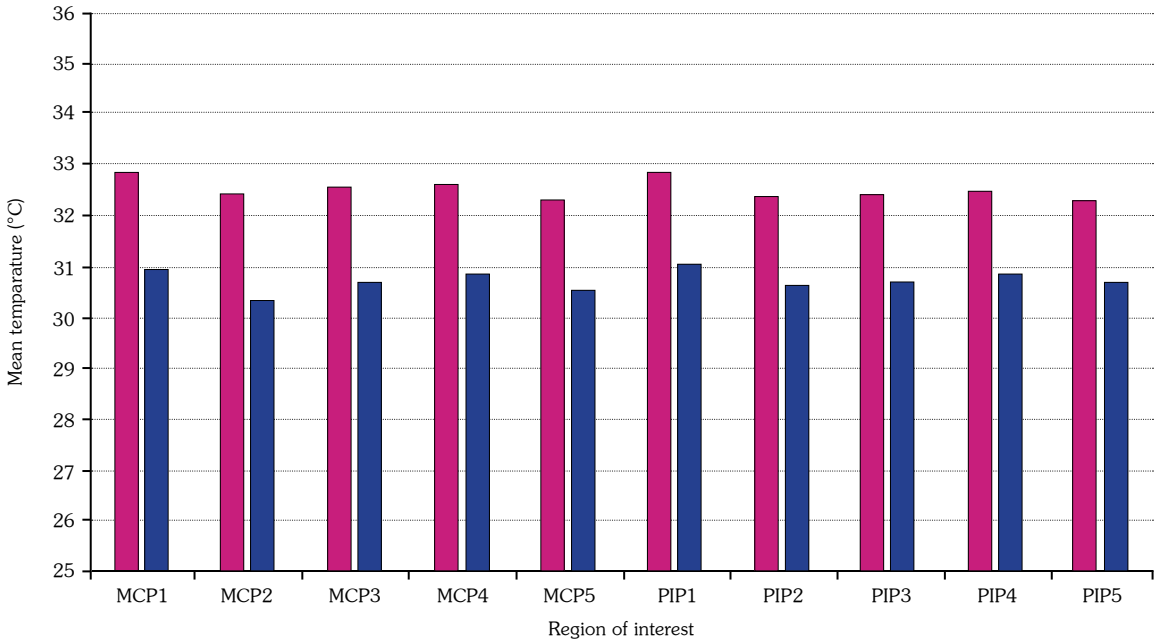

Figure 2. The mean temperatures for the left hand.
MCP: Metacarpophalangeal; PIP: Proximal interphalangeal.

+ csDMARDs + bDMARDs, and 18 patients were on DMARDS only. One patient was on bDMARD only. The mean DAS28 score of the patients was 3.7±1.7 and mean HAQ score was 2.35±0.58. Ten of the patients with RA were in remission. Nine patients had low disease activity, 24 had moderate disease activity and nine had high disease activity.

The mean temperature in MCP (1-5) and PIP (1-5) joints of both hands was significantly higher in RA patients compared to healthy controls ($p<0.05$). The mean temperature values of MCP and PIP joints for the right and left hand are represented Figures 1 and 2. The mean temperature values of the joints in the RA patients with RAI score of 0, 1, 2, 3 were 32.43±1.59°C; 32.71±1.36°C; 33.12±1.23°C; 33.60±0.99°C, respectively. The mean temperature was 31.14±1.50°C in healthy controls. The mean temperature values of the joints in the RA patients with RAI score of 0 had high temperature compared to healthy controls ($p<0.05$). Patients with a Ritchie sensitivity score of 1 had a higher mean temperature compared to patients with 0 ($p<0.05$). In RA patients, the joints with RAI score of 1 had higher mean temperature values than the joints with RAI score 0 ($p<0.05$). The mean temperature values of the joints with RAI score of 2 were also higher than the joints with RAI score 1 ($p<0.05$). The mean temperature values of the joints with RAI score of 3 were also higher than the joints with RAI score 2; however, there was no statistically significant difference ($p>0.05$).

DISCUSSION

In the present study, we compared thermographic patterns in RA patients and healthy controls and examined differences in thermographic patterns between tender and non-tender joints in RA patients. Our study results showed that there was a significant difference between RA and healthy controls. In recent years, studies on the use of thermography in rheumatic diseases have increased and different results have been reported. Studies examining thermography in patients with osteoarthritis (OA) have revealed a correlation between radiographic severity and joint surface temperature in both hand and knee OA.[16,17] Denoble et al.[16] used thermography for

comparing patients with radiographic OA (rOA) with a Kellgren-Lawrence (KL) Grade 2 and 3 and controls who had no knee pain and knee OA. The aforementioned study showed positive associations between rOA severity and joint temperature values.

The effectiveness of thermal imaging has also been evaluated in juvenile rheumatic diseases. Lasanen et al.[18] investigated the effectiveness of thermal imaging in 58 pediatric patients with sign of inflammation in their joints. In the study, results of thermal imaging were compared to clinical evaluation of the knee and ankle joint and it was found that the temperature was higher in the inflamed ankle joint. Gatt et al.[19] compared the thermographic patterns in the feet of patients with RA in clinical and radiological remission and healthy controls. The authors reported that patients with RA in remission had higher temperatures compared to the controls. In their study, RAI was used to evaluate joint tenderness and joints with a RAI score of >0 were excluded. In our study, we also used RAI to evaluate joint tenderness. In accordance with the RAI, the joints of RA patients were scored from 0 to 3, and joints with no tenderness were not excluded. By including patients with joint tenderness scores of 0, we attempted to evaluate RA patients with and without joint tenderness. We found that RA patients with no joint tenderness had higher temperature than healthy controls. One of the main results of our study was that the mean temperature reached the highest in the joints with a RAI score of 3, while it was the lowest in the joints with a RAI score of 0 in patients with RA. In addition, we observed that the mean temperatures were higher in the joints with a RAI score of 2 than joints with a score of 1. Another critical point of the study was that mean temperatures in non-tenderness joints of patients with RA were higher than the healthy group. Jones et al.[20] investigated the utility of thermography in demonstrating disease activity in the small joints of the hand. Joint temperature was found to be higher in patients for MCP and PIP joints. On the other hand, the study did not show any relationship between joint temperature and disease activity parameters such as swollen joints, CRP, and ESR. Vasdev et al.[21] evaluated the knee joints of patients with RA and healthy controls in terms of thermal changes. All participants underwent power Doppler ultrasound (DUS) and thermal evaluations. The study showed a high difference in mean knee temperatures between RA patients and healthy individuals. In addition, inflammation shown by power DUS was associated with a high temperature difference in the knee joint. Taken together, these findings support the correlation between thermography and other imaging modalities, such as DUS, in demonstrating disease activity. In another study, Morales-Ivorra et al.[22] developed the Thermographic Disease Activity Index (ThermoDAI) and ThermoDAI-CRP using the CRP, Patient Global Assessment (PGA) and ThermoJIS which they advanced with machine learning in their previous studies. The study indicated that ThermoDAI and ThermoDAI-CRP had a moderate and strong correlation with ultrasound PD score, respectively. It showed that ThermoDAI and ThermoDAI-CRP had a strong correlation with DAS28-CRP, CDAI and SDAI and study emphasized that ThermoJIS, PGA and CRP were synergistic and thermography provide an accurate evaluation of synovitis in RA.

A limitation of our study was the small number of patients with very high disease activity. Therefore, the relationship between joint temperatures and disease activity could not be evaluated.

In conclusion, our study indicated that the mean temperature in the non-tender joints of patients with RA was higher compared to healthy controls, suggesting that thermographic measurements is emerging a valuable diagnostic tool that can be used together with imaging methods and laboratory tests in the diagnosis of RA. These findings suggest that thermography may be an objective tool for assessing disease activity in RA patients, owing to different mean temperatures observed in the joints which show different scores of RAI. In the future, thermography may be used as a complementary method for patients to self-assess disease activity. We believe that these results have the potential to serve as a foundation for developing artificial intelligence applications. Further studies with a larger

number of patients would pave the way for the clinical use of the proposed method.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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