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# Using Thermography Infrared to Detect Diabetic Foot Ulcers in Asia Pacific Countries: Scoping Review

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## A B S T R A C T

**Introduction:** Diabetes Mellitus (DM) is a growing global health concern, particularly in Indonesia, where the prevalence is projected to rise significantly. Diabetic Foot Ulcer (DFU) is a severe complication of DM that escalates the risk of amputations. Early detection of DFUs plays a crucial role in preventing associated complications **Objective:** This review aimed to assess the efficacy of infrared thermography in detecting DFUs in the Asia-Pacific region. **Methods:** A scoping review methodology adhering to PRISMA guidelines was employed. Databases were searched from 2011-2021. PICO strategy used keyword Diabetic foot ulcer, Skin ulcer, Leg ulcer, Foot ulcer, Diabetic neuropathic, Thermography, Temperature mapping, and Detection from PubMed, Scopus, Google Scholar, and Science Direct. Quality of article assessed by JBI. **Results:** Four (4) studies meeting the inclusion criteria were identified, primarily cross-sectional in design. The results indicated promising sensitivity and specificity of infrared thermography in detecting DFUs among DM patients. The technology's ability to capture thermal images revealing temperature variations associated with tissue inflammation, a common DFU indicator, underscores its efficacy. This non-invasive technique allows for early detection and monitoring of DFUs, facilitating timely interventions and improving patient outcomes. Additionally, infrared thermography provides a quantitative and objective assessment of tissue health, complementing traditional visual inspection and palpation methods. Its effectiveness lies in detecting subtle skin temperature changes, aiding in early identification and management of DFUs before they progress to more severe stages. **Conclusion:** Infrared thermography shows significant potential in detecting DFUs early, which is vital for effective management and prevention of severe complications. Despite the promising results, broader and more rigorous studies are necessary to validate these findings across different populations and healthcare settings. Further research across diverse settings and study designs is essential to reinforce these findings.

## 1. INTRODUCTION

Diabetes Mellitus (DM) is a chronic disease whereas pancreas not enough to product insulin or body useless insulin effectively("Global Report on Diabetes," 2016). International Diabetes Federation (IDF) reported DM patients in world increased in 2017 around 425 million to 629 million in 2045(Cho et al., 2018). In other hand, according to IDF's data, in 2045 DM patients in Indonesia will increase to 16,7 million from 10,3 million in 2017(Cho et al., 2018). Thus, showing that DM in worldwide is increasing.

Diabetic foot ulcer (DFU) is common complication in DM patients. Prevalence of DFU in some countries are varies(Zhang et al., 2017). A systematic review reported DM patients had risk amputation 10-20 times compared patients had no DM (Moxey et al., 2011). Early detection will help to prevent and decrease risk amputation.

To date, many tool had developed to detect DFU, one of them detecting change of temperature using infrared thermography(Bus et al., 2021; Ilo et al., 2020; Liu et al., 2015; Petrova et al., 2018). Early detection is important so that recurrence do not happen. In many countries, this tool had already developed. Therefore, this study aims to evaluate effect infrared thermography to detect DFU in Asia Pacific countries.

The existing literature may not provide a comprehensive overview of how infrared thermography is utilized specifically for DFUs in the Asia-Pacific region. A scoping review can map out what has been studied, the methodologies used, and the findings reported. In addition, by summarizing and analyzing the current state of research, a scoping review can highlight gaps in knowledge, such as the lack of studies in certain countries or regions within the Asia-Pacific.

This review was conducted in the Asia-Pacific region due to the high prevalence of diabetes, socio-economic and healthcare access variations, cultural diversity, diverse environmental conditions, and the significant potential for health policy development and local research enhancement. By understanding the specific conditions of this region, this review aimed to provide insights that can improve the detection and management of diabetic foot ulcers, ultimately enhancing public health in the Asia-Pacific. The question of this study is whether infrared thermography had an effect on detecting DFU?

## 2. METHODS

**Design Study**

Scoping review design was used in this study and also was carried out by the Preferred Reporting Item for Systematic Review and Meta-Analysis (PRISMA) (Moher et al., 2009). What is effectiveness of thermography infrared to detect DFU is question to guide the review in this study.

**Eligibility Criteria**

For guiding question and search for article, we used PICO strategy, which is an acronym for Patient/Problem (diabetic mellitus), Intervention (thermography infrared), Control/Comparison and Outcome (no intervention/diabetic foot ulcer) (Mamédio et al., 2007). Experimental or quasi-

experimental design, such as randomization or without randomization with a single group pre- and post-test, observational, including prospective cohort, case control and cross-sectional studies were considered in this review. Inclusion criterions in this review as following: 1) conducted in Asia Pacific countries between 2011-2021, 2) diabetic patients 3) using thermography infrared to detect diabetic foot ulcers and 4) published only in English. Studies involving healthy participants, systematic or literature reviews, and research that did not address the study question or lacked a clear methodology were excluded.

**Information Sources**

The searching of data source in the following databases: PubMed, Google Scholar, Scopus dan Science direct. The searches were conducted from 2011 to 2021.

**Searching Strategy**

Keyword in search used MESH and free text including; "*Diabetic foot ulcer*", "*Skin ulcer*", "*Leg ulcer*", "*Foot ulcer*", "*Diabetic neuropathic*", "*Thermography*", "*Temperature mapping*", "*Detection*". Meanwhile, searching in google scholar used keywords; "*Using thermography on diabetic foot ulcer*".

**Article Screening**

The searching was carried out by the main researcher, who forwarded to three review authors (ST, JN and RM) independently reviewed the title and abstract of all studies. The same step also was taken for full-text screening. Data was extracted according to standardized form including first author's last name, year publication, country, participant characteristics, study design and findings of the study.

**Data Extraction and Critical Appraisal**

For quality, all article were assessed by four reviewers (HY, LE, MM and MO) independently using checklist form by The Joanna Briggs Institute Critical Appraisal tool for cohort prospective  (12 questions) (Moola, Munn, Tufanaru, Aromataris, Sears, Sfetcu, et al., 2017), and cross-sectional (8 questions) (Moola, Munn, Tufanaru, Aromataris, Sears, & Sfetcu, R Currie M, Qureshi R, Mattis P, Lisy K, 2017). Studies were chosen based on a quality evaluation, requiring an assessment score exceeding 60% of the total.

## 3.  RESULTS
**Search Results and Included Studies**

The initial search returned 6,125 studies from different databases. After screening 919 full-text articles, the authors excluded 915 studies that didn't meet the inclusion criteria. As a result, 4 studies were included in this scoping review. Figure 1 displays the number of retrieved studies, depicted in the PRISMA flow chart diagram.

**Study Characteristics**

Data extraction was based on Table 1, comprising authors, year of study, country, sample, design, and outcomes. According to the review results, one study was prospective, while three were cross-sectional. The studies were conducted in China, Australia, Japan, and Singapore. The average age of participants ranged from 36.2 years to 63 years. The follow-up time was determined at week 4.
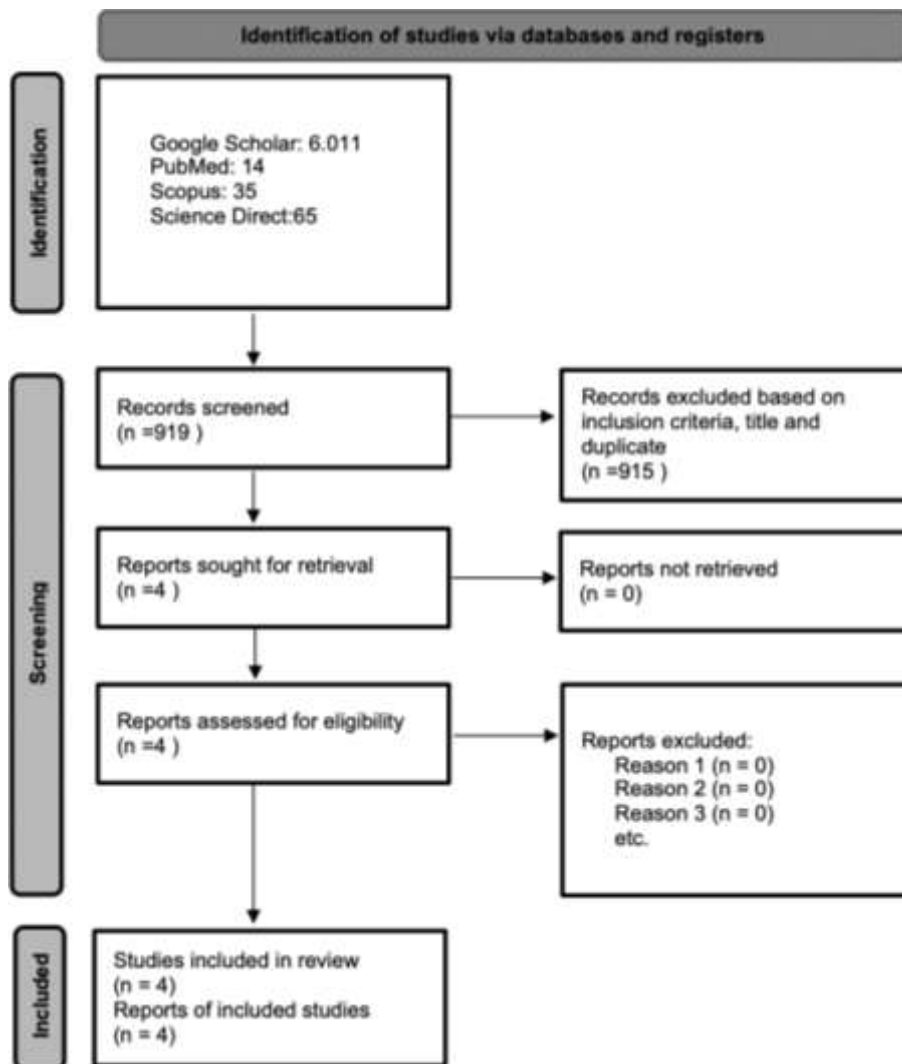


**Figure 1. Steps for Article Screening Using PRISMA**

**Risk of Bias Assessment**

According to the risk of bias assessment, the studies overall exhibited a low risk of bias. Among them, several studies reported follow-up assessments with the lowest score being greater than 87.5% (Table 1).

**Tabel 1. Summary of Results and Research Quality**

| Authors | Year | Country | Sample | Design Study (Quality value) | Results |
|---|---|---|---|---|---|
| Zhou Q | 2020 | China | 60 Diabetic foot ulcers 60 Healthy | Cross sectional 8/8 (100%) | Detection of skin temperature over blood vessels using infrared has excellent test-retest reliability. There is no difference in skin temperature based on gender and age. However, there is a difference in skin temperature over the posterior tibial artery between foot ulcer patients and healthy individuals. |
| Aliahmad B | 2019 | Australia | 11 Healing 15 Non Healing | Prospective, longitudinal, observative 11/12 (91,7%) | In healing wounds, the wound base area ratio decreased by the 2nd week compared to non-healing wounds. Changes in temperature can predict healing status by the 4th week. |
| Adam M | 2018 | Singapore | 51 Healthy 66 Diabetic foot ulcers | Cross sectional 7/8 (87,5%) | Accuracy of 93.16%, sensitivity of 90.91%, and specificity of 98.04% using thermograms on both feet. |
| Nagase T | 2011 | Japan | 32 Healthy 129 Diabetic foot ulcers | Cross sectional 8/8 (100%) | Thermography can be an option for assessing circulation status in daily foot care and surgical interventions. |

## 4. DISCUSSION

Currently, there have been numerous studies utilizing infrared in detecting diabetic wounds. However, this is the first scoping review to examine the use of infrared in detecting diabetic wounds in the Asia-Pacific region. Our search highlighted articles that had analyzed and compared foot temperatures using infrared thermography in both healthy individuals and diabetic patients (Adam et al., 2018; Nagase et al., 2011; Zhou et al., 2021), and also wound healing on diabetic patients (Aliahmad et al., 2019).

All four articles utilize thermal imaging technology to understand or diagnose diabetes-related conditions. Each article focuses on the application of this technology for early detection or management of medical conditions associated with diabetes. They aim to enhance understanding or diagnostic methods using thermal imaging technology, exploring its potential in improving the detection and management of diabetic complications.

However, each article has a specific focus and objective depending on the particular aspect of thermal imaging use. Methods and analytical approaches vary among the articles despite their common use of thermal imaging technology. These differences are evident in the adoption of diverse analytical techniques such as wavelet transform methods, thermographic pattern analysis, or the development of automated detection methods. These varying approaches underscore the multidimensional application of thermal imaging in enhancing diagnostic precision and management strategies for diabetes-related conditions across different research contexts (adapted).

First article highlights the importance of non-invasive approaches in detecting neurological complications that are often challenging to diagnose at early stages without clear symptoms. By utilizing infrared thermal imaging, the study found that temperature changes at specific points on the skin can provide early indications of neuropathy. The findings suggest that thermal imaging technology holds significant potential in improving early detection and management of peripheral neuropathy in diabetic patients, potentially enhancing quality of life and preventing more serious complications (Zhou et al., 2021).

Second article investigates if infrared imaging can provide insights into the progression and healing outcomes of diabetic foot ulcers by analysing thermal patterns. The research aims to establish whether thermal signatures correlate with different stages of ulcer healing, potentially offering a non-invasive method to monitor healing progress. Findings suggest promising associations between thermal characteristics and ulcer healing status, demonstrating the potential utility of thermal imaging in predicting and monitoring the healing process of diabetes-related foot ulcers (Aliahmad et al., 2019).

Third article focuses on developing an automated method to detect diabetic foot conditions, both with and without neuropathy, using a complex wavelet transform technique. The study aims to improve diagnostic accuracy and efficiency by analyzing foot thermograms. By applying the double density-dual tree-complex wavelet transform, the research explores its effectiveness in differentiating thermal patterns indicative of neuropathy in diabetic patients. The findings suggest that this automated approach holds promise for enhancing early detection and management of diabetic foot complications through advanced thermal imaging analysis (Adam et al., 2018).

The last article explores differences in thermal patterns on the soles of the feet between healthy individuals and diabetic patients without ulcers. The study introduces a novel classification method based on the angiosome concept, which divides the foot into distinct vascular territories. By analyzing thermographic data, the research identifies unique thermal variations associated with diabetic conditions, potentially aiding in early detection and management strategies. The findings suggest that this approach could provide valuable insights into the vascular health of diabetic patients and contribute to more targeted interventions to prevent complications such as ulcers (Nagase et al., 2011).

The benefits of thermal imaging technology highlighted in the four articles are substantial, emphasizing its importance in diabetic care. Firstly, it offers non-invasive early detection capabilities for diabetic peripheral neuropathy (Zhou et al., 2021), aiding in timely intervention to prevent further nerve damage. Secondly, it serves as a potential predictor for healing status of diabetes-related foot ulcers (Aliahmad et al., 2019), facilitating better management and treatment

decisions. Thirdly, automated detection methods using complex wavelet transforms on foot thermograms (Adam et al., 2018), improve diagnostic accuracy, crucial for prompt medical interventions and preventing complications. Lastly, the novel classification based on angiosome concepts (Nagase et al., 2011), provides insights into vascular health and early signs of complications like ulcers, enabling targeted preventive measures. Given the chronic nature and severity of diabetic complications, focusing on these advancements in thermal imaging technology is crucial. They not only enhance early detection and management but also contribute significantly to improving the quality of life for diabetic patients by reducing the risk of debilitating complications.

Infrared thermography creates a visual representation of heat and a thermogram is the image produced by this process, utilizing photographic film that is sensitive to infrared radiation or the record generated by a thermograph (Bandalakunta Gururajarao et al., 2019). Thermography is used to detect unusual temperature variations in diabetic patients, particularly in their lower limbs (Maddah & Beigzadeh, 2020). Thermography can be used to assess inflammation in diabetic feet (Rob F.M. van Doremalen et al., 2020), to detect of diabetic foot complication (Van Netten et al., 2013), and can identify localized temperature variations in diabetic feet that are at high risk (Ilo et al., 2020).

The diagnostic accuracy of infrared thermography demonstrated sensitivity rates of 94% and 93%, along with specificity rates of 86% and 91% (R F M Van Doremalen et al., 2019), *accuracy of 93.16%, sensitivity of 90.91%, and specificity of 98.04%* (Adam et al., 2018).

This review is limited due to its inclusion of studies solely conducted in the Asia-Pacific region, potentially restricting the generalizability of the findings to populations within that geographical area. Additionally, the absence of results from randomized controlled trials (RCTs) is a notable limitation, as it may diminish the strength of evidence or conclusions drawn from this review. Therefore, further research from diverse geographical regions and different study designs is needed to strengthen the findings presented in this review.

## 5. CONCLUSION

Infrared thermography is effective in detecting DFU due to its ability to capture thermal images that reveal temperature variations associated with tissue inflammation, which is a common indicator of DFU. This non-invasive technique allows for early detection and monitoring of DFUs, potentially leading to timely intervention and improved patient outcomes. Additionally, infrared thermography provides a quantitative and objective assessment of tissue health, complementing traditional visual inspection and palpation methods. Its effectiveness lies in its ability to detect subtle changes in skin temperature, aiding in the early identification and management of DFUs before they progress to more severe stages.

## 6. ACKNOWLEDGEMENT

## 7. CONFLICT OF INTEREST

The authors state no conflict of interest.

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