Seasonality in Foot Inflammation Detected by a Telemedicine Once-Daily Temperature Monitoring Mat

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Purpose
Seasonal variation in the incidence of diabetic foot wounds is an understudied factor. The existing literature on the topic is scattered, and limited to retrospective studies of amputations rates in temperate northern hemispheres. This study should be scheduled to avoid appointments in late winter and early spring in order to proactively remind patients to perform daily foot checks before a season of increased activity. Researchers also suggested that in future studies, average temperature should be analyzed instead of the raw data to account for temperature on the progression of diabetic foot ulcers (DFU). Armstrong et al concluded that cold weather can act as a preventative factor through patient activity, whereas the data was not analyzed adequately for this purpose.

Results
Our data demonstrate that over three years of observation, higher foot inflammation occurs in months when the weather is more conducive to outdoor activity. In our American southwest cohort, the average inflammation (characterized as the number of scans showing signs of inflammation over a 4 day period and the percentage of scans that showed visual changes in the DFU) was significantly higher during the Winter months and lowest during the Summer months, shown in orange in Figure 1. By comparing inflammation data to environmental temperatures in that area, shown in blue in Figure 1, we gain insight into this seasonal pattern. Figure 1 also demonstrates increased inflammation around the American holidays in November and December. Figure 2 shows the decrease in inflammation as environmental temperatures increase to uncomfortable heat, such as 90 degF to over 100 degF.

Figure 1: Percentage of scans with inflammation on each date plotted against daily average temperature during those dates.

We analyzed three days of daily foot temperature data generated from a telemedicine remote temperature monitoring mat, pictured in Image 1 (Podimetrics RTM System; Podimetrics Inc.; Somerville, MA). Patients used the Podimetrics mat once-daily indoors, and the ambient temperature in patients’ homes during the period studied was 75.3 ± 3.3 degF. It is a Class 1 FDA cleared device and is calibrated to accurately assess dorsal foot temperatures over a range of 39 degF to 104 degF. Our cohort consisted of 542 high-risk patients living in the American southwest (Image 2). More than 400,000 foot temperature readings, or "scans," were collected from these patients during this period. We assessed the percentage of scans on any given day that showed signs of inflammation, which we defined as temperature difference exceeding 4 degF between a patient’s left and right foot.

We qualitatively evaluated the trends in inflammation over the three-year period. Finally, we evaluated historical daily weather data in the geographic area of our cohort using the National Oceanic and Atmospheric Administration (NOAA) records and overlaid the number of inflammation scans with the corresponding weather data for that day.

In Phoenix, Arizona, USA during the past 20 years the outdoor average high temperature June through September (Summer months) was 104 degF, whereas December through March (Winter months) was 71.2 degF (Table 1) [1]. Thus, the Winter months in this geographic location tend to have the most comfortable ambient conditions, which may be more active outside of their home.

Aims: We hypothesized that patients are more active during these Winter months, going for more walks and outings compared to other seasons where environmental factors cause discomfort and are avoided. This presumed increase in activity results in more frequently detected inflammation. Furthermore, we predict a higher percentage of inflammation can be seen occurring around holidays specific to the US, such as Thanksgiving in November, religious holidays in December and, or acute injuries around Independence Day.

Table 1: Average maximum temperature in Phoenix, AZ during Jun-Aug and Dec-Mar.

<table>
<thead>
<tr>
<th>Season</th>
<th>Temperature (degF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td>104.0 degF</td>
</tr>
<tr>
<td>Winter</td>
<td>71.2 degF</td>
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</tbody>
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Limited current literature studied injury outcomes of two isolated populations in northern climates, concluding that an increase in activity related to winter weather months correlates to an increase in foot wound occurrence [1,2]. Our analysis is consistent with these findings in the sense that all three studies report poorer outcomes (or more inflammation, presumably associated with power activity) during comfortable environmental conditions, such as favorable weather for activity.

One benefit of this study is that markers of ongoing inflammation are reported instead of an outcome. This discovery leads to speculation that the wounds observed in the two prior publications, Armstrong 1997 and Leung 2007, were likely the result of repetitive microtrauma through increased or variational activity, as opposed to acute injury.

Figure 2: Percentage of scans showing inflammation gathered during different average environmental temperatures.

Conclusions
The seasonal increase of a patient’s daily foot temperature asymmetry from July to January can be seen in Figure 3, as well as the spikes in inflammation during the American holidays in late November and December. The thermogram which brought attention to an ulcer on this patient’s hallux is seen in Figure 4. This case study comes from Kelchen et al [10], where a subset of our cohort in Arizona was investigated. The limited patient data and lack of daily foot temperature data to this point makes it difficult to see significant seasonal increases in foot inflammation due to consistent and irregular foot activity. This could be remedied with previous research findings which conclude that increased foot activity correlates with increased inflammation.

Once-daily foot temperature monitoring is an evidence based practice for detecting and monitoring foot inflammation. Supported by three randomized control trials [3-5] and recommended by three clinical practice guidelines [7-9], once-daily thermometry allows for remote monitoring of ongoing foot inflammation. In our study, using a remote temperature monitoring mat to detect foot inflammation and hot spots, innovative data were collected and aligned with seasonal variations. Our approach differs from the literature, which utilized retrospective data and hospital outcomes data in primarily northern climates. Our data show ongoing inflammation in an arid climate, confirming the conclusions made by these previous studies as well as holding high clinical implications for affecting the approaches toward diabetic foot complication risks and injury prevention per the season.

Changes in climate can alter a patient’s lifestyle, which in turn can cause activity driven injury to the diabetic foot. Thus, seasonal need may be accounted for when assessing the risk of foot health. For example, frequent clinic visits can be scheduled preceding the months with climate conducive to active activity in order to check for proper fitting footwear and encourage regimented preventive habits regarding foot health. Foot complications, such as callus formation, may be taken more seriously when considered during the time of year.

In summary, the addition of new telemedicine monitoring will create an increase in notifications based on seasonal variations. Inflammation which is consistently driven by preferable weather and daily activity will increase. The once-daily activity monitoring paired with once-daily foot temperature scans would be a valuable contributor to future research. Increased activity may also occur due to increased leisure time for travel or other hobbies. Ultimately, our seasonal patterns support the need for once-daily inflammation monitoring via telemedicine during these high-risk times of year.

References and Acknowledgements

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