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Brief Report

The environment has effects on infrared temperature screening for COVID-19 infection

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A B S T R A C T

Infrared temperature measurement is a common form of mass screening for febrile illnesses such as COVID-19 infection. Efficacy of infrared monitoring is debated, and external factors can affect accuracy. We determine that outside temperature, wind, and humidity can affect infrared temperature measurements and partially account for inaccurate results.

Infrared imaging systems (IRIs) and non-contact IR thermometers (NCITs) have been used for mass screenings during outbreaks of the SARS, Ebola, Dengue, and Influenza H1N1 viruses.[1−3] Across the United States, entry screening procedures for COVID-19 infection have been implemented according to the CDC guidelines, including a brief questionnaire and temperature measurement. There is evidence, however, that screening for fever is inadequate in the detection of infected individuals and preventing spread.[2,4]

Firstly, in patients admitted for COVID-19 infection, fever was only present in 43.8%. Fever developed in 88.7% of patients during hospitalization, however, indicating a significant lag between infection and fever and that some patients may never become febrile.[5]

Next, screening methods vary. During the pandemic, NCITs and IRIs were widely adopted due to the ability to measure temperature without physical contact. Infrared cameras measure temperature radiation from the body across a plane from multiple points.[3] NCITs are less costly than IRIs, but only measure temperature radiation from a single point. However, both IRIs and NCITs are less accurate than tympanic thermometers for fever detection as accuracy depends on distance from the subject and the angle of measurement.[6]

Because IRIs and NCITs measure skin temperature to determine core temperature, discrepancies may be found between measured and actual values due to the physiologic thermoregulatory responses.[3,4,6−8] Segments of the face have unequal heat distribution, with the inner canthi and external auricle having the highest correlation with core temperature.[2,6,9] Measurements are also affected by exposure to direct sunlight[7] and physical exertion.[8]

In a review of infrared imaging use during pandemics, Perpetuini et al. reported significant difference in measured temperatures obtained by IRI versus oral temperatures. Even with specific cutoff values and correctional algorithms, the sensitivity for detecting fever ranged from 70% to 93% between studies, indicating other factors may influence measurements.[3] In a controlled study of 92 volunteers, Dzien et al found that in cold environments, infrared body temperature was lowest and varied the most immediately upon entering an establishment, but trended towards normal with time inside.[4] Therefore, we hypothesize that environmental factors account for the discrepancy in reported sensitivities due to a direct effect on infrared temperature measurements. We attempted to determine correlations between infrared body temperature and environmental factors including outside temperature, humidity, weather, and wind velocity.

METHODS

Between March 9th and March 15th, 2021, every patient and visitor entering a medical center in Louisville, Kentucky was asked a brief screening questionnaire and screened for fever with one of two NCITs

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Table 1
Summary statistics of infrared body temperature measurements by group. IQR, interquartile range

IR Temperature (n)	Mean	Std. Dev.	Range	IQR
Experimental (3351)	35.8°C	0.51	5.6	0.67
Control (1079)	36.1°C	0.47	3.3	0.72
Total (4430)	35.8°C	0.52	5.6	0.67
Outside Temperature	13.2°C	5.4	18.9	10.6
Wind Velocity	5.4 m/s	2.6	10.3	4.5
Relative Humidity	49.3%	19.4	74.0	27.0

which were used in tandem and interchangeably. [Extech IR200 (Extech Instruments, Waltham, Massachusetts, USA), Visiofocus PRO 06480 (Tecnimed, Varese, Italy)] All monitors were calibrated prior to use per company standards.

Data were recorded in hourly intervals. Data were analyzed by entrance used and the distance from outside, and collectively with comparisons between the shorter distance group (labelled experimental) and the control group which had the furthest indoor distance.

Continuous weather data were recorded via the National Weather Service from the closest location to the medical facilities, 4.62 miles away. Outside temperature, precipitation (on a scale from strong sunshine to heavy rain), relative humidity, and wind velocity were analyzed as continuous variables using STATA IC/16.1. Frequency data were reported in mean, range, and standard deviation. Correlations were determined using Student's T test with a 95% confidence interval and multivariate linear regression with controls for collinearity.

This study was approved by the institutional IRB and determined exempt as no identifiable health information were recorded.

RESULTS

Over the course of one week, 4430 patients and visitors were screened at the entry booths. Average body temperature was 35.8°C [32.1-37.7 ± 0.52°C]. No patients or visitors were turned away for fever.

The distance between outside and the screening booths were 9.4 meters, 11.3 meters, 12.2 meters in the experimental group and 32.0 meters in the control group. Mean infrared body temperature measurements were 0.34°C higher [$P < .001$, CI 0.31-0.38] in the control group. Overall skew was right shifted in the experimental group (0.148) but not the control. Summary statistics are included in Table 1.

The average outside temperature during hours when subject data was collected was 13.2°C [3.9-22.8, ± 5.4]. The average relative humidity was 49.3% [19-93% ± 19.4%]. Average wind velocity was 5.4 m/s [0-10.3 ± 2.6]. Wind gusts were excluded from the regression as they were significantly colinear with wind velocity. Weather ranged from partly cloudy to heavy rain.

Outside temperature had a positive linear correlation with infrared body temperature. Relative humidity negatively correlated with body temperature measurements in the experimental group but not the control group. The most significant environmental effects occurred with screening booths closer to the outside door, indicating that distance inside lessened the environmental effects on NCIT measurements. Furthermore, the average infrared temperature was higher and the standard deviation was lower in the control group, indicating both more accurate and more precise measurements with a further inside distance to screening. Precipitation did not correlate with infrared temperatures to a statistically significant degree. Multivariate linear regression is presented in Table 2.

DISCUSSION

The average measured infrared body temperatures indicate that NCITs are not an adequate screening tool for fever. Despite the prevalence of COVID-19 and other febrile infections, not a single febrile subject was detected or denied entrance.

Our data agree with a growing body of literature that infrared body temperature screening is not an adequate screening technique.[2,4,10,11] To our knowledge, our study is the first to quantify the effects of environmental factors on infrared body temperature measurements in a large population.

While the correlation with environmental factors was statistically significant, the coefficient and R^2 were not high enough to calculate an equation for correction, indicating that many other factors also influence temperature measurements. However, the linear correlations were significant enough that environmental effects could cause a normal temperature measurement in a truly febrile subject.

Our study had several limitations. First, we did not have a gold standard temperature measurement to compare with our recorded data. Because of this, it is possible that there were no febrile subjects in our sample population. Secondly, all outside temperatures during the study period were lower than physiologic body temperature, which could impact our results and implications for warmer climates. Furthermore, there were no periods of strong sunshine, which could have similar implications. Lastly, we used just 2 of the more than 200

Table 2
Multivariate linear regression: Effect of environmental factors on infrared body temperature measurements. Standard errors in parentheses. $^{**}P < .01$, $^{*}P < .05$

	Experimental	Control	Total
VARIABLES	Infrared Temperature	Infrared Temperature	Infrared Temperature
Outside Temperature (°C)	0.0203**	0.0165**	0.0186**
	(0.00201)	(0.00354)	(0.00176)
Wind Velocity (m/s)	-0.0222**	-0.0226**	-0.0248**
	(0.00397)	(0.00660)	(0.00342)
Relative Humidity (%)	-0.112*	-0.0184	-0.131**
	(0.0546)	(0.0891)	(0.0467)
Precipitation	0.00278	0.0139	0.00298
	(0.00475)	(0.00829)	(0.00414)
Distance from Outside (m)	-0.0397**		0.0155**
	(0.00686)		(0.000809)
Constant	36.08**	35.92**	35.53**
	(0.0916)	(0.110)	(0.0573)
Observations	3,351	1,079	4,430
R-squared	0.050	0.024	0.107

available infrared screening tools. This study may not be applicable to all available devices. Future study could be performed in warmer climates to determine if correlations remain.

CONCLUSION

Infrared temperature measurement by non-contact infrared thermometer underestimates body temperature and may be inadequate in detecting fever. A statistically significant correlation exists between infrared body temperature and outside temperature, relative humidity, and wind velocity, but not precipitation. These effects could cause a normal result in a truly febrile subject, but the effects were reduced with a greater physical distance from outside to the measurement area.

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SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.ajic.2021.08.002.

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