Mass Thermography Screening for Infection and Prevention: A Review of the Clinical Effectiveness [Internet].

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Excerpt

Thermography involves the quantification of emitted radiation to measure temperature, and provides a quick non-invasive means to measure body temperature. Infrared thermography (IRT) can be implemented at international airports in order to detect febrile passengers and prevent the introduction and spread of infectious diseases to other countries. Border control strategies were enacted as a response to the emergence of Severe Acute Respiratory Syndrome (SARS) in 2003, which included the introduction of non-contact infrared thermal scanners at international airports and bus or railway stations for mass screening of individuals. IRT has also been used as a measure to detect and prevent influenza outbreaks and transmission of dengue fever across borders. IRT may be influenced by several confounding factors including age and outdoor temperature. In addition, results from studies looking at IRT as a tool to detect fever tend to have small positive predictive values due to the small prevalence of febrile passengers. However, advantages of using IRT include its ability to screen mass numbers of individuals and reduce close contacts with infected individuals. Recently, the 2014 Ebola epidemic in West Africa has renewed concerns of disease transmission across borders and increased vigilance to identify individuals entering the country who may harbour infection. The purpose of this review is to examine the effectiveness of screening for fever at border crossings to reduce the risk of infectious disease outbreaks.

Sections

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CONTEXT AND POLICY ISSUES

Thermography involves the quantification of emitted radiation to measure temperature, and provides a quick non-invasive means to measure body temperature.[1] Infrared thermography (IRT) can be implemented at international airports in order to detect febrile passengers and prevent the introduction and spread of infectious diseases to other countries.[2] Border control strategies were enacted as a response to the emergence of Severe Acute Respiratory Syndrome (SARS) in 2003, which included the introduction of non-contact infrared thermal scanners at international airports and bus or railway stations for mass screening of individuals.[2] IRT has also been used as a measure to detect and prevent influenza outbreaks and transmission of dengue fever across borders.[2]

IRT may be influenced by several confounding factors including age and outdoor temperature.[3] In addition, results from studies looking at IRT as a tool to detect fever tend to have small positive predictive values due to the small prevalence of febrile passengers.[3] However, advantages of using IRT include its ability to screen mass numbers of individuals and reduce close contacts with infected individuals.[2] Recently, the 2014 Ebola epidemic in West Africa has renewed concerns of disease transmission across borders and increased vigilance to identify individuals entering the country who may harbour infection.[4]

The purpose of this review is to examine the effectiveness of screening for fever at border crossings to reduce the risk of infectious disease outbreaks.

RESEARCH QUESTION

What is the effectiveness of screening for fever at border crossings to reduce the risk of outbreaks?

KEY FINDINGS

One prospective study found that infrared thermography readings correlated moderately well with temperature readings taken using a conventional method (oral, aural, or axillary). One prospective study and four retrospective studies found that fever screening using a combination of infrared thermography, health declaration forms, and a conventional method at international airports had low sensitivity for detecting influenza viruses and dengue fever. There were no studies that assessed how border control strategies would mitigate the risk of disease outbreaks.

METHODS

Go to:

Literature Search Strategy

A limited literature search was conducted on key resources including PubMed, The Cochrane Library (2014, Issue 10), University of York Centre for Reviews and Dissemination (CRD) databases, Canadian and major international health technology agencies, as well as a focused Internet search. No filters were applied to limit the retrieval by study type. Where possible, retrieval was limited to the human population. The search was also limited to English language documents published between January 1, 2004 and October 15, 2014.

Go to:

Selection Criteria and Methods

One reviewer screened citations and a second reviewer selected studies based on full-text review. In the first level of screening, titles and abstracts were reviewed and potentially relevant articles were retrieved and assessed for inclusion. The final selection of full-text articles was based on the inclusion criteria presented in Table 1.

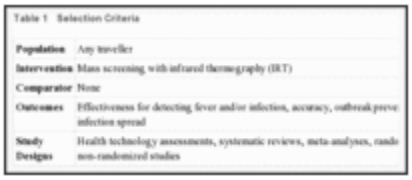

Table 1 Selection Criteria

Population	Any traveller
Intervention	Mass screening with infrared thermography (IRT)
Comparator	None
Outcomes	Effectiveness for detecting fever and/or infection, accuracy, outbreak prevention, infection spread
Study Designs	Health technology assessments, systematic reviews, meta-analyses, randomized and non-randomized studies

Table 1

Selection Criteria.

Go to:

Exclusion Criteria

Studies were excluded if they did not satisfy the selection criteria, if they were duplicate publications, or were published prior to 2004.

Go to:

Critical Appraisal of Individual Studies

The quality of included non-randomized studies were evaluated using the Downs and Black instrument.[5] A numeric score was not calculated for each study. Instead, strengths and limitations of each study were summarized and described.

CONCLUSIONS AND IMPLICATIONS FOR DECISION OR POLICY MAKING

Fever screening was implemented at border crossings after the global outbreak of SARS, which prompted countries to set up border control strategies.[2] According to the included studies, fever screening at international airports was generally not effective at detecting H1N1-2009 and other influenza viruses, or dengue fever. One study performed in a controlled setting assessed how well IRT readings correlated with conventional methods and found only moderate correlation. The study concluded that IRT would not be suitable as a routine screening tool due to the high number of false positives. Relatively low sensitivity and positive predictive values were also seen in studies looking at fever as a predictor of influenza or dengue fever. The reason for these results may be due to the delayed appearance of febrile symptoms for these infectious diseases. Infection associated with the influenza virus begins a few hours before the onset of symptoms, and the viremia of dengue begins one day before the onset of febrile symptoms, making it difficult to detect cases via fever screening.[8]

The Ebola epidemic in West Africa was declared a public health emergency of international concern by the World Health Organization on August 8, 2014.[4] The Ebola virus has an average 8 to 10 day incubation period (range 2 to 21 days) during which the traveller would experience no symptoms.[4] This would make it difficult to detect travellers who have been recently infected with the virus at border screenings.

Fever screening in the included studies consisted of a combination of health declaration forms, IRT, a conventional temperature measurement and laboratory testing to confirm diagnosis. Despite using all of these methods, results showed that fever screening was not a very effective strategy at detecting infected individuals. A limitation of this review was the lack of studies that assessed how border control strategies would mitigate the risk of disease outbreaks.

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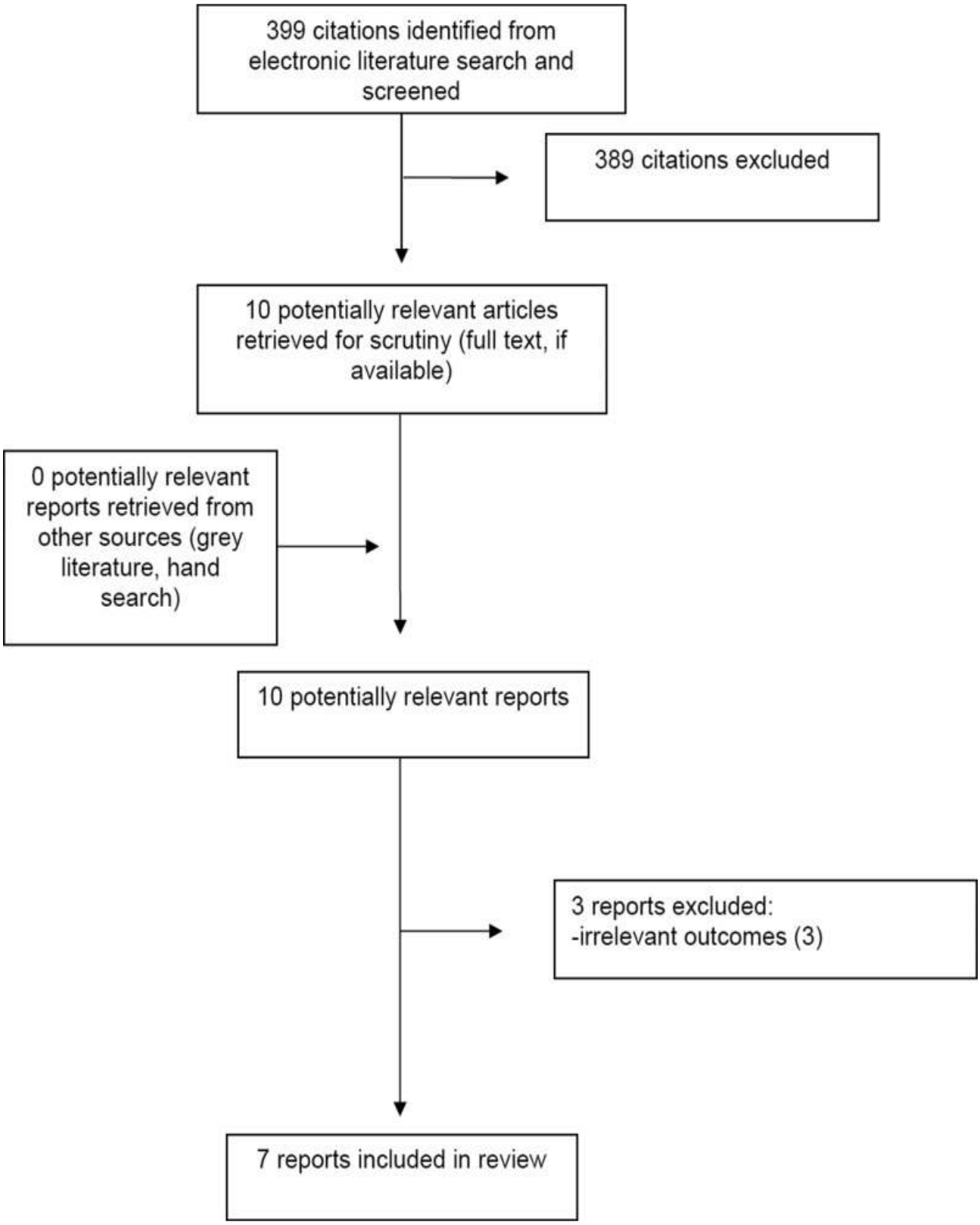
APPENDIX 1Selection of Included Studies



APPENDIX 2Characteristics of Included Studies

First Author, Publication Year, Country	Study Design, Location, Length	Participants	Intervention(s)	Outcomes Measured
Febrile Detection				
Cho[6] 2014 Korea	Retrospective study using health declaration forms and interview records International airport Jan 1-Dec 31, 2012	584,323 arrivals 355,887 (60.9%) from quarantinable countries 608 subjects reporting at least one health-related symptom	Fever screening to detect febrile arrivals (thermal camera set for 36°C, tympanic temperature scanner, health declaration forms) Brands of thermoscanner: Thermovision A20M, FLIR; Thermo Tracer TH7800; ThermoGraphy R300	Prevalence of febrile arrivals (defined as tympanic temperature above 37.8°C), association between fever measurements and thermal camera temperature
Chan[10] 2013 Hong Kong	Prospective study Hospital Oct 2005-Jul 2006	1517 participants (770 women) recruited from the accident and emergency department of a hospital	Infrared thermography (forehead, temples, nose, mouth cheeks, ear, neck) versus core temperatures measured by conventional oral thermometry or aural temperature (higher measurement) to detect fever (core temperature ≥38°C)	Correlation between IRT and core temperatures

First Author, Publication Year, Country	Study Design, Location, Length	Participants	Intervention(s)	Outcomes Measured
H1N1 and Influenza				
Gunaratnam[7] 2014 Australia	Retrospective study Sydney Airport Apr 28-Jun 18, 2009	625,147 arrivals 5845 symptomatic or febrile 1296 identified as requiring further assessment 3 confirmed with H1N1-2009	Thermal imaging scanners (set point 38°C ± 2°C), health declaration form, clinical assessment, nose and throat swab	Detection rate, sensitivity, specificity, PPV
Nishiura[3] 2011 Japan	Retrospective study using 2 different datasets (dataset 1: confirmed H1N1 or influenza cases; dataset 2: suspected passengers detected by infrared thermoscanner) Narita international airport Dataset 1: Apr 28-Jun 18, 2009	Dataset 1: 441,041 passengers and 30,692 airline crew members 805 passengers underwent rapid diagnostic testing 18 confirmed cases of influenza (10 H1N1, 7 influenza type A, 1 influenza type B)	Fever screening using infrared thermoscanner (TVS-500, NEC/AVIO Infrared Technologies Co. Ltd.) set at 35.4°C threshold, axillary temperature measurement, self-report or reports by relatives/friends to detect H1N1-2009 or influenza	Sensitivity and specificity of IRT in detecting hyperthermia, positive predictive value, correlation between IRT and axillary temperature

First Author, Publication Year, Country	Study Design, Location, Length	Participants	Intervention(s)	Outcomes Measured
	Dataset 2: Sept 2009-Jan 2010	Dataset 2: 9,140,435 passengers screened 1,049 selected and suspected passengers (self-reported symptom, reported by relatives or friends, detected by IRT) had axillary temperature measured		
Priest[11] 2011 New Zealand	Prospective study Christchurch international airport Aug 21-Sept 12, 2008	5274 travellers returned a questionnaire 823 were symptomatic 1275 airline travellers had IRT screening, tympanic temperature measurement and respiratory sampling	Influenza border screening: Infrared image thermal scanner (ThermaCAM E45, FLIR Systems), tympanic temperature – threshold 37.8°C (ThermaScan PRO 4000, Braun), swab for respiratory sampling, screening questionnaire	Accuracy of IRT in predicting tympanic temperature
Dengue Fever				

First Author, Publication Year, Country	Study Design, Location, Length	Participants	Intervention(s)	Outcomes Measured
Kuan[8] 2012 Taiwan	Retrospective study Taoyuan (4 entry gates) and Kaohsiung (1 entry gate) international airports 2007–2010	Inbound passengers 2007: 12,508,621 2008: 12,202,392 2009: 12,499,365 2010: 14,837,391 Confirmed febrile passengers (%) 2007: 11,118 (0.09) 2008: 12,158 (0.10) 2009: 12,286 (0.10) 2010: 12,553 (0.08) Dengue importations detected in airport fever screening 2007: 72 2008: 100 2009: 108 2010: 126	Active surveillance Infrared thermal camera at each entry gate set at 37.5°C, ear thermometer (fever defined as temperature > 38°C), Dengue NS1 Rapid Test Kit and central laboratory used to confirm diagnosis Passive surveillance Hospital-based reporting system for the notification of either imported or domestic dengue cases.	Sensitivity, Specificity, PPV, NPV
Shu[9] 2005 Taiwan	Retrospective study Taoyuan (4 entry gates) and Kaohsiung (1	>8,000,000 inbound passengers ~22,000 passengers	Active surveillance Infrared thermal camera at each entry gate set at 37°C, ear	Proportion of dengue cases identified by active surveillance

First Author, Publication Year, Country	Study Design, Location, Length	Participants	Intervention(s)	Outcomes Measured
	entry gate) international airports Jul 2003-Jun 2004	identified as fever patients by infrared thermal camera and rechecked by ear temperature 3011 serum samples sent for laboratory diagnosis 40 serum samples confirmed to be positive based on RT-PCR	thermometer (fever defined as temperature > 37.5°C), RT-PCR and ELISA to confirm dengue fever diagnosis. Passive surveillance Hospital-based reporting system for the notification of either imported or domestic dengue cases.	

IRT = infrared thermoscanner; NPV = negative predictive value; PPV = positive predictive value; SARS = severe acute respiratory syndrome

APPENDIX 3Summary of Critical Appraisal

First Author, Publication Year, Country	Strengths	Limitations
Febrile Detection		
Cho[6] 2014 Korea	• Large population screened • All participants were measured with both thermal scanner and tympanic temperature scanner • No participants lost to follow-up • Duplicate retrieval of data	• Small number of febrile arrivals • Sample was enriched with suspected fraction of patients • Arrivals detected as having fever by thermal camera but asymptomatic not included
Chan[10] 2013 Hong Kong	• Large population enrolled • All participants were measured with both infrared thermography and a conventional method	• Study was performed in a controlled setting and not in a real-world setting • Participants were recruited from a Hong Kong hospital, which may not be representative of the general population • It was unclear whether there was a time gap between both temperature measurements
H1N1 and Influenza		
Gunaratnam[7]2014 Australia	• Large population screened • Screening practices reflected real-world	• No gold standard for temperature measurement employed • Study was specifically detecting H1N1-2009 and influenza, and

First Author, Publication Year, Country	Strengths	Limitations
	conditions	may not be generalizable to other diseases
Nishiura[3] 2011 Japan	• Large population screened • All participants had both IRT and axillary temperature measurements	• A retrospective non-random sample was used, representing a suspected fraction of patients that may not be representative of the general population • Study was specifically detecting H1N1-2009 and influenza, and may not be generalizable to other diseases
Priest[11] 2011 New Zealand	• Large population screened • Screening practices reflected real-world conditions • All participants had both IRT and tympanic temperature measurements	• Included sample was enriched with symptomatic travellers, which may not be representative of general population • Study was specifically detecting influenza, and may not be generalizable to other diseases
Dengue Fever		
Kuan[8] 2012 Taiwan	• Large population screened • Screening practices reflected real-world conditions • All participants were measured with both infrared thermography and a conventional method	• Study was specifically detecting dengue, and may not be generalizable to other diseases

First Author, Publication Year, Country	Strengths	Limitations
Shu[9] 2005 Taiwan	• Large population screened • Screening practices reflected real-world conditions • All participants were measured with both infrared thermography and a conventional method	• Study was specifically detecting dengue, and may not be generalizable to other diseases

APPENDIX 4Summary of Findings

First Author, Publication Year, Country	Main Study Findings	Authors' Conclusions
Febrile Detection		
Cho[6] 2014 Korea	Fever screening identified 6 febrile arrivals based on a tympanic temperature above 37.8°C - Fever prevalence 0.002% (6/355,887) - 1% of 608 symptomatic arrivals had fever - There was no statistically significant difference between thermal camera scanning (average temperature 36.83°C) and tympanic temperatures (38.14°C) of the febrile arrivals	"This study also finds no significant difference between thermal camera temperature and ear temperature. Therefore, an array of the procedures employed by quarantine stations in Korea-health declaration form, thermal camera scanning, and subsequently tympanic temperature measurement-could service as useful complements to one another in detecting febrile arrivals as accurately as possible." (p. 5)
Chan[10] 2013 Hong Kong	Correlation coefficients between infrared thermography and conventional temperature measurements (n=1517) AREAMAX (maximum frontal temperature): 0.434 FOREHEAD (forehead temperature): 0.361 LATMAX (maximum lateral temperature): 0.440 Febrile subjects: range 0.224 to	"Infrared thermographic temperature correlates only moderately with core temperature, but performs better in children, men, and among febrile subjects. The IRT temperature is inversely proportional to the distance from the camera. Although the study results suggested better test performances using either the maximum lateral or frontal temperature, their sensitivity might still not be high enough and the high

First Author, Publication Year, Country	Main Study Findings	Authors' Conclusions
	0.328 Non-febrile subjects: 0.241 to 0.273 <u>AUROC (95% CI)</u> AREAMAX: 0.812 (0.761 to 0.863) FOREHEAD: 0.780 (0.723 to 0.837) LATMAX: 0.815 (0.763 to 0.867) <u>Effects of distance on infrared thermography temperature reading recorded (n=31)</u> IRT temperature decreased on average by 0.3°C per meter increase in distance from the camera.	number/proportion of false positives would be overwhelming. This property renders IRT unsuitable as a routine screening tool for febrile conditions, especially at border crossings with huge numbers of passengers. A single IRT measurement of the forehead from a distance should be replaced by a method with greater sensitivity and specificity." (p. 114)
H1N1 and Influenza		
Gunaratnam[7] 2014 Australia	Of the 1296 passengers identified as requiring further assessment: - 1144 (88.27%) were detected through health declaration cards - 11 (0.85%) were detected by thermal scanners - 35 (2.70%) identification method unknown or other 5845 passengers were identified	"Our analysis shows that airport screening in NSW during pandemic (H1N1) 2009 influenza had low sensitivity, detecting far fewer cases during the DELAY and CONTAIN phases compared with emergency departments or general practitioners…The small number of passengers detected by thermal scanners is also consistent with published estimates of the sensitivity of non-contact infrared thermal image scanners, and the high proportion of influenza infections that are likely to be asymptomatic." (p. 2014)

First Author, Publication Year, Country	Main Study Findings	Authors' Conclusions
	as symptomatic or febrile, and 3 were subsequently confirmed as having H1N1-2009. There were 45 people with overseas-acquired H1N1-2009 that would have probably passed through the airport during this time. Sensitivity: 6.67% (95% CI 1.40 to 18.27) Specificity: 99.10% (95% CI 99.00 to 100.00) PPV: 0.05% (95% CI 0.02 to 0.15)	
Nishiura[3] 2011 Japan	<u>Dataset 1</u> Of the 16 confirmed cases of influenza: - 9 were male - 13 were under medication upon arrival Using a cut-off level of 37.5°C or 38.0°C, the sensitivities of hyperthermia for detecting influenza was 22.2% (95% CI, 0 to 56.0) for H1N1 and 42.9% (95% CI, 14.3 to 85.7) for other influenza viruses. Using a cut-off level of 38.5°C, the sensitivities of hyperthermia for detecting influenza was 11.1% (95% CI, 0 to 33.3) for H1N1 and 28.6% (95% CI, 0 to 57.1) for other influenza viruses.	"Among the confirmed H1N1-2009 cases (n = 9), the sensitivity of fever for detecting influenza upon arrival appeared to be as low as 22.2%, and 5 of the 9 cases (55.6%) were under antipyretic medications. The PPV or the infrared thermoscanners for detecting fever among the suspected fraction of passengers (n = 1,049) was shown to be insufficient to actively detect febrile influenza cases among passengers. Given the additional presence of confounding factors and unrestricted medications among passengers, the reliance on fever alone is unlikely to be feasible as an entry screening measure against influenza." (p. 10)

First Author, Publication Year, Country	Main Study Findings	Authors' Conclusions
	Age, gender, and medications were not associated with hyperthermia. The proportion of hyperthermia cases was smaller among those with medications for both cut-off levels of 37.5°C and 38.0°C <u>Dataset 2</u> 1049 screened passengers had axillary temperature readings. Mean axillary temperature: 37.6°C ± 1°C Mean IRT temperature: 36.3°C ± 0.9°C Correlation coefficient between IRT and axillary temperature readings: 0.44 ($p < 0.01$) The surface temperatures as measured by IRTs were statistically significantly higher among those defined as having hyperthermia ($p < 0.01$). Using the cut-off levels of 37.5°C, 38.0°C and 38.5°C, the sensitivities were estimated to be 58.3%, 50.8% and 70.4% and the specificities were estimated to be 70.5%, 81.7% and 63.6%, respectively. The PPV ranged from 37.3% to 68.0% and NPV ranged from 61.1% to 87.5%. The AUROC ranged from 74.0% to 75.9%.	

First Author, Publication Year, Country	Main Study Findings	Authors' Conclusions
Priest[11] 2011 New Zealand	7 travellers had a tympanic temperature of ≥ 37.8°C (5 symptomatic) <u>IRT as a predictor of tympanic temperature (n = 1275) using a definition of fever of ≥ 37.8°C tympanic temperature</u> **IRT of front of face** AUROC (95% CI): 0.86 (0.75 to 0.97) Sensitivity: 86% Specificity: 71% Estimated PPV: 1.5% **IRT of side of face** AUROC (95% CI): 0.76 (0.54 to 0.97) Sensitivity: 86% Specificity: 51% Estimated PPV: 0.9% **Temperature as a predictor of influenza infection** 30 samples were positive for influenza (3 Type A, 27 Type B) - 27 were symptomatic - 0 had a measured tympanic temperature of ≥ 37.8°C	"In this study, during a seasonal epidemic of predominantly influenza type B, influenza-infected arriving travellers had a very low prevalence of fever. Consequently, IT IS would not have identified influenza-infected travellers even though it performed moderately well at detecting febrile travellers. Some aspects of this study may not generalise to a pandemic of Influenza A. Although febrile illness is more common in influenza A infections than influenza B infections, many influenza A infections are afebrile. Our findings therefore suggest that ITIS is unlikely to be effective for entry screening of travellers to detect influenza infection with the intension of preventing entry of the virus into a country." (p. e14490)
Dengue Fever		
Kuan[8] 2012	Overall, 44.9% (95% CI 35.73 to 54.13) of the confirmed	"A moderate sensitivity of 44.93% and a PPV that ranged from 1.28–

First Author, Publication Year, Country	Main Study Findings	Authors' Conclusions
Taiwan	imported dengue cases with apparent symptoms were detected by the thermal screening program. PPV: 2.36% (95%CI 0.96 to 3.75) NPV: >99.99% Specificity: 99.97% (95% CI 99.96 to 99.97) Percentage of imported symptomatic dengue cases detected at entry 2007: 40.2 (72/179) 2008: 44.3 (100/226) 2009: 52.9 (108/204) 2010: 41.5 (126/304)	3.22% were obtained for airport fever screening in this study. Our findings indicated some limitations of the airport fever screening programs for preventing the introduction of dengue. However, these procedures might help to target some symptomatic dengue importations for an immediate self-quarantine that might mitigate some local dengue transmissions." (p. 9)
Shu[9] 2005 Taiwan	Airport fever screening identified 40 of 48 (83.3%) of all imported cases identified by the active surveillance system. Percentage of imported symptomatic dengue cases detected at entry: 65.8 (48/73)	"Our results demonstrated that fever screening at airports is an effective means of identifying imported dengue cases, whereas the health statements of inbound passengers, which have been required for years, are ineffective." (p. 461)