The use of non-invasive thermometers in healthcare facilities: a scoping review protocol

Siti Zubaidah Mordiffi1,2 • Micah D.J. Peters3 • Emily N.K. Ang1

1Singapore National University Hospital (NUH) Centre for Evidence-Based Nursing: a Joanna Briggs Institute Centre of Excellence, Singapore, 2Nursing Department, National University Hospital, Singapore, and 3The Joanna Briggs Institute, Faculty of Health and Medical Sciences, University of Adelaide, Adelaide, Australia

Review objective and questions: The objective of the review is to map the available evidence to provide an overview of the use of non-invasive thermometers in the general context of health care. The specific questions, in regards to the available international published and unpublished literature, are:

• What types of non-invasive thermometers have been used?
• What manufacturers/brand of thermometers have been used?
• What routes have been used for the thermometers?
• What thermometers have been used as reference thermometers?
• What measures of accuracy have been reported in studies comparing different thermometers and routes of temperature measurement?
• How have included studies reported on comparisons of different thermometers in terms of frequency of thermometer readings, time that temperature is measured and factors affecting accuracy?

Keywords Accuracy; body temperature; in-patient; temperature; thermometer

Background

In healthcare facilities, vital signs are measured to monitor the patient’s physiological condition and progress of their illness. Body temperature is one of four vital signs that are monitored when a person is ill.1 Abnormal body temperature, such as hypothermia or hyperthermia, may indicate signs of illness and warrant treatment.2 The temperature of patients who are admitted to healthcare facilities is measured as part of standard routine medical care. Indications for measuring the patient’s body temperature are, for the purpose of establishing the baseline temperature, close observations for timely detection of hypothermia or hyperthermia, for observing and monitoring fever (a sign of infection), monitoring effects of antimicrobial therapy and observing for signs of transfusion reaction.1

Failure of thermometers to accurately measure body temperature may result in missed abnormal body temperatures, which may compromise patient safety when deterioration is not detected in a timely manner.1 The normal thermic range is between 36°C and 37.5°C.1,3 Early signs of hyperthermia may manifest in giddiness, confusion, delirium and exhaustion, whereas persons with hypothermia may manifest loss of memory, depression, poor judgment, decreased heart rate, respiration rate and blood pressure.4 In people with fever (hyperthermia), for every 1°C rise in temperature, there is a 10% increase in the rate of enzyme controlled chemical reactions.5 At 43°C or higher, irreparable cell damage and enzyme denaturation occurs, resulting in death. Conversely, in the case of hypothermia, as body temperature decreases below 33°C, cellular processes become sluggish.5 As the metabolic rate falls, loss of consciousness may occur and, potentially, death. Body temperatures should therefore be measured accurately and reliably as temperature is an important factor that influences diagnoses and the determination of the resulting treatment plan.1

Core temperature at sites such as the heart and the brain are the most accurate “true” representation of
body temperature. The temperature at these areas are tightly regulated and are most accurate. However, they are invasive and are not easily accessible or convenient. While there are different views regarding which site is the most accurate, the most accurate core temperature can only be taken through invasive routes such as via the esophagus and pulmonary artery. This degree of accuracy may be required for critically ill patients and these invasive methods are most feasible in highly acute care areas such as intensive care units or operating rooms. In less-acute care settings, invasive measurement of core temperature is unduly complex, carries an unnecessary risk to patients and is summarily unfeasible.

For these reasons, a less-invasive, simpler and safe method is likely to be a preferred option for both patients and clinicians. Non-invasive sites that provide the best estimation of core temperatures include oral, axillary, temporal artery and external auditory canal (tympanic) due to their proximity to the core regions of the body and the presence of large blood vessels. Thus, temperatures taken from peripheral or “near core” sites are more commonly and conveniently used. However, these thermometers have limitations as they are more likely to be affected by ambient temperatures. This explanation highlights the significance of the differences between the measurement of core temperature and surface temperature and concomitantly, the necessity of accurate thermometers for the measurement of both.

User technique can also impact upon accuracy of temperature readings. This has been identified in previous studies. In one study, the accuracy of a temporal artery scanner thermometer was measured against a disposable temporal artery thermometer. The temporal artery scanner thermometer was not as sensitive as the disposable temporal artery scanner thermometer in detecting patients with fever. The results of this study led to a recommendation that more research is required to identify accurate and reliable non-invasive thermometers.

An initial search of the JBI Database of Systematic Reviews and Implementation Reports, the Cochrane Database of Systematic Reviews, MEDLINE (PubMed) and CINAHL, Google and Google Scholar was conducted in November-December 2015. A published scoping report was located related to this topic. This scoping report evaluated temporal artery thermometers, infrared in-ear thermometers and reference standard thermometers used at various sites (rectal, pulmonary artery, oral, brain and bladder). The temporal artery thermometers measured the body temperature on the forehead and behind the ear. While findings of the review were inconclusive, temporal artery thermometers were slightly more accurate than in-ear thermometers. A limitation of this review was that the focus was solely on contact temporal artery and tympanic thermometers; this proposed scoping review will not have these restrictions. Furthermore, the review reported no information on the brands evaluated. An additional limitation of the older review is that more recently published evidence around non-contact temporal artery thermometers is now available. For these reasons, a broader, more detailed scoping review is warranted to map the current literature.

The search also sought existing systematic reviews on the accuracy of non-invasive thermometers. Two were located. One evaluated accuracy of infrared tympanic, rectal and oral peripheral thermometers and compared them with pulmonary artery and bladder thermometers in febrile patients. This review concluded that tympanic and oral thermometers provide an accurate measure of core temperature and highlighted the dearth of papers on some brands of peripheral thermometers currently used in clinical practice. The review also reported major statistical flaws in many studies. This resulted in the exclusion of studies considering bladder thermometers. The exclusion of a number of papers was acknowledged by the authors as a potential source of publication bias. As the present scoping review will seek to map all relevant literature regardless of quality, this limitation will be avoided. The other systematic review evaluated the accuracy of infrared tympanic, temporal artery, axilla and oral peripheral thermometers against pulmonary, urinary bladder, esophageal or rectal central thermometers in both adults and children from acute care or ambulatory facilities. In contrast to the previous review, this review concluded that the peripheral thermometers do not have clinically acceptable accuracy and should not be recommended in acute settings. Nevertheless, in less-acute areas, electronic oral and tympanic membrane thermometers were recommended for practical reasons. This review included studies that evaluated mercury thermometers that are now obsolete due to toxicity risks. In both reviews, the studies
included were from inception up to 2010, and July 2015, respectively. These existing reviews focused upon differing issues and reported conflicting results that limit their usability for improving clinical practice; however, as a scoping review, the present review will include these papers. To provide necessary clarity, it is important that a scoping review that also reports additional information such as the brand and route of thermometer is conducted. This scoping review will adopt the methodology for JBI scoping reviews.

In summary, accurate measurement of body temperature is integral to the identification of many illnesses and provision of efficient and good quality health care. Currently in practice, a diverse range of thermometers are used for the measurement of patients’ body temperature and frequently vary both in terms of type and manufacturer. Furthermore, there are a number of routes used by clinicians to measure patient body temperature. Each of these variables are known to be potentially influential upon the accuracy of body temperature estimation. Because there is currently no “gold standard” thermometer type, manufacturer or route, published and unpublished studies do not use a standard reference thermometer in comparison studies of the accuracy of thermometers. This also means that there is currently a lack of clarity around what a “hospital grade” thermometer is. How thermometers are compared and accuracy is measured also appears to be inconsistently reported across studies, including previous systematic reviews. It is therefore important that a scoping review be conducted to provide a clear map of thermometer use within health care; what thermometers are used in terms of type and manufacturer, what routes are commonly used for each and what thermometers are most commonly used as reference thermometers. In addition, it will also be important to develop an understanding of how accuracy has been measured and thermometers compared across the available literature.

Inclusion criteria

Types of participants
The current scoping review will consider studies that include adults and children of all ages where body temperature is taken non-invasively regardless of whether they are normothermic or hypo/hyperthermic.

Concept
The concepts examined by this scoping review are the various types, routes and brands of non-invasive thermometers to measure peripheral body temperature and where comparisons are made with reference thermometers in terms of accuracy. The non-invasive thermometers to be included are hospital-grade thermometers used in the clinical context. Thermometers for home-use and mercury-in-glass thermometers will be excluded.

Specific data to be extracted from the included studies will include:
- Reported types of non-invasive thermometers including test and reference thermometers.
- Reported manufacturers/brand of thermometers.
- Reported routes that are used for the thermometers.
- Reported measures of accuracy in studies comparing different thermometers and routes of temperature measurement.
- Data pertaining to comparisons of different thermometers in terms of, for example, frequency of thermometer readings, time that temperature is measured and factors affecting accuracy.

Context
The current scoping review will consider studies that have been conducted in healthcare facilities of any type including, but not restricted to, hospitals, medical centers and long-term care facilities. Studies from any geographic setting will be eligible for inclusion.

Types of studies
The current scoping review will consider method-comparison studies, quasi-experimental studies, diagnostic studies and so on for inclusion. Other types of studies such as systematic reviews and quality improvement projects will be also considered.

Search strategy
The search strategy will aim to find both published and unpublished English language studies. An initial limited search of MEDLINE (PubMed) and CINAHL will be undertaken to identify articles on this topic, followed by analysis of the text words contained in the titles and abstracts, and of the index terms used to describe these articles. This will inform
the development of a search strategy including identified keywords and index terms that will be tailored for each information source. A full search strategy is provided in Appendix I. Due to advancements in the last 15 years away from mercury-in-glass thermometers that are now widely considered to be obsolete, this scoping review will include only evidence relevant to present clinical practice published from 2001 to present. The reference lists of all included studies will be screened for additional studies.

The databases to be searched will include:
- CINAHL
- MEDLINE (Ovid)
- Science Direct
- Embase
- Scopus
- Health Source
- Cochrane Central Register of Controlled Trial (CENTRAL)
- Health Technology Assessment Database (HTA)
- Cochrane Database of Systematic Reviews
- JBI Database of Systematic Reviews and Implementation Reports

The search for unpublished studies will include:
- ProQuest Dissertation and Theses
- Google Scholar/Google

**Data extraction**

Data will be extracted by two independent reviewers from papers included in the scoping review using the draft data extraction tool listed in Appendix II. The data extracted will include specific details about the populations, concept, context and study methods of significance to the scoping review questions and specific objectives. Any disagreements that arise between the reviewers will be resolved through discussion or with a third reviewer. Authors of papers will be contacted to request missing or additional data where required. The draft data extraction tool will be modified and revised as necessary during the process of extracting data from each included study. Additional types of relevant data may be extracted from included studies as determined by the review team during the course of the conduct of the scoping review in line with the Joanna Briggs Institute methodology. Modifications will be detailed in the full scoping review report.

**Presenting the data**

The extracted data will be presented in diagrammatic or tabular form in a manner that aligns to the objectives and questions of this scoping review. The tables and/or charts will report on distribution of studies by type, brand, route and reported accuracy measures of non-invasive thermometers, year of publication, countries of origin, area of practice (clinical), research methods and findings. Additional data identified that is relevant to the review objectives will also be presented in diagrammatic or tabular form. A narrative summary will accompany the tabulated and/or charted results and will describe how the results relate to the review’s objective and questions.

**References**


## Appendix I: Logic grid for initial search

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<thead>
<tr>
<th>Draft search terms</th>
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<tr>
<td><strong>Participants</strong></td>
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<tr>
<td>Adult OR children of all ages</td>
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<td><strong>Concept</strong></td>
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<td>Surface body temperature:</td>
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<td>- Route – e.g. oral OR temporal artery OR tympanic OR axilla OR “body temperature”</td>
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<tr>
<td>- Brands – all brands (hospital grade), thermometer(s)</td>
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<tr>
<td>Reference temperature:</td>
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<tr>
<td>- Route – e.g. pulmonary artery OR, esophageal, OR bladder OR rectal</td>
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<tr>
<td><strong>Context</strong></td>
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<tr>
<td>Healthcare facilities e.g. tertiary hospital, rehabilitation hospital, community hospitals, medical centers, nursing homes etc.</td>
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<tr>
<td><strong>Study types</strong></td>
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<tr>
<td>Method-comparison, quasi-experimental and diagnostic</td>
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<tr>
<td>Systematic reviews, technical reports and quality improvement</td>
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Appendix II: Draft data extraction instrument

<table>
<thead>
<tr>
<th>Author (y)</th>
<th>Setting/population</th>
<th>Method/statistical analysis</th>
<th>Reference thermometer</th>
<th>Comparison thermometer</th>
<th>Results</th>
<th>Author’s conclusion</th>
<th>Reviewer comments</th>
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