Comparative Evaluation of Non-Mercury Thermometers in Nabatieh Governmental Hospital and Healthcare Staff Preferences

by

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ABSTRACT

Background – Mercury is one of the world's most ubiquitous heavy metal neurotoxic substances used in healthcare facilities. The United Nations Environment Programme (UNEP) and the World Health Organization have identified the adverse effects of mercury pollution as a serious global environmental and human health problem. The World Health Organization is leading a global initiative to achieve virtual phasing out of mercury-based thermometers and sphygmomanometers over the next decade and their substitution with accurate, economically viable alternatives.

Rationale – In Lebanon, some private hospitals have replaced mercury thermometers with high-end electronic thermometers rather than standard digital clinical thermometers. Understanding the basis for the choices made by healthcare professionals could inform the process of cost-effective mercury phase-out planning.

Aims of the project – This project aims to evaluate non-mercury thermometers and recommend the better alternative for the healthcare sector in Lebanon.

Design/Methodology – Two approaches were utilized in this descriptive study:

1) Data gathering from vendors and in a clinical setting (one rural governmental hospital) to identify specific characteristics of the two non-mercury thermometers
2) Comparison of perceived characteristics of the two thermometers by a sample of personnel from each hospital ward

Results – Survey of medical vendors revealed the availability of 20 brands of compact electronic, electronic, infrared tympanic, infrared temporal, and Galinstan-in-glass thermometers in the Lebanese market. Nurse managers' preferences regarding the characteristics of the alternative thermometer favored an electronic thermometer, Suretemp Plus 690 (Welch Allyn – USA) and a compact electronic thermometer, MT200 (Microlife, Switzerland). The costing model utilized showed that the electronic thermometer is the most cost effective type of thermometers. Evaluation of the accuracy showed statistically and clinically significant differences between the readings of the two thermometers. Healthcare professionals needed significantly less time to produce a measurement with the electronic thermometer. Healthcare staff favored electronic thermometer regarding ease of use, patient friendliness, and infection control; while compact electronic thermometer was more favored for durability. Trust in the performance of both thermometers was a challenge, less for the electronic thermometer.

Conclusion – Electronic thermometers were found to be the most cost effective, user friendly, accurate, and nursing preferred alternative to mercury thermometers in the Lebanese healthcare market.

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UNEP: United Nations Environment Programme

WHO: World Health Organization

GEF: Global Environment Facility

UNDP: United Nations Development Programme

MOE: Ministry of Environment

NGH: Nabatieh Governmental Hospital

IRB: Institutional Review Board

USD: United States Dollars

ASTM: American Society for Testing and Material

BS EN: British Standard European Norm

LoA: Limits of Agreement

1 INTRODUCTION

Mercury is a metal found in many healthcare devices including thermometers, sphygmomanometers, esophageal tubes, and batteries, among others. It is released into the environment either through breakage of the containing equipment or through incineration. It bioaccumulates in nature and is so toxic that a drop of mercury as small as 1/70 of a teaspoon can contaminate a 25-acre lake to the point that the fish will be unsafe to eat (Sattler, 2002). It causes a myriad of effects on humans including neuropathy, hypertension, renal damage, depressed immunity, and infertility, among others (Sattler, 2002). The United Nations Environment Programme (UNEP) and World Health Organization have identified the adverse effects of mercury pollution as a serious global environmental and human health problem (UNEP, 2002; World Health Organization [WHO], 2007).

Healthcare facilities are one of the most prominent sources for mercury pollution of the environment. Lebanon imports on average 427517 liquid-filled mercury thermometers annually, which is equal to 214 Kg of mercury mass (UNDP, August 2007). Most of these thermometers end up in the open dumpsters where they are broken and mercury content is released. It is estimated that the healthcare sector in Lebanon releases around 31 Kg of mercury to the environment every year from improper disposal of mercury thermometers and sphygmomanometers, with an emission factor of 2.8 grams of mercury per bed per year (UNDP, August 2007). Health Care Without Harm and the World Health Organization are co-leading a global initiative to achieve virtual phasing out of mercury-based thermometers and sphygmomanometers over the next decade and their substitution with accurate, economically viable alternatives. This initiative is based on the 2005 WHO Policy Paper, which calls for short, medium and long-term steps to achieve the gradual substitution of mercury-based medical devices (WHO, 2005).

The Global Environment Facility (GEF) in collaboration with the United Nations Development Programme (UNDP) is conducting a global healthcare waste project aimed primarily to promote the use of non-burn waste treatment technologies, improve waste segregation practices and the use of appropriate alternatives to mercury-containing devices (UNDP, August 2007). The project is run simultaneously in eight countries including Lebanon and is implemented under the authority of the Lebanese Ministry of Environment (MOE).

The gold standard for measuring core body temperature non-invasively is the rectal mercury thermometer; however, this method is being replaced by more comfortable, faster, and easier to use alternatives (Paes, Vermeulen, Brohet, van der Ploeg, & de Winter, 2010). Electronic, chemical, infrared, and liquid-in-glass thermometers are the available alternatives for mercury thermometers. These thermometers differ in accuracy when compared to mercury thermometers and studies have not established consistent evidence that can be generalized to all hospital settings and patient populations regarding which type of thermometer is the most reliable to use (Dodd, Lancaster, Craig, Smyth, & Williamson, 2006; Greenes & Fleisher, 2001; Hebbar, Fortenberry, Rogers, Merritt, & Easley, 2005; Jensen, Jensen, Madsen, & Løssl, 2000; Kistemaker, Den Hartog, & Daanen, 2006; Rosenthal

& Leslie, 2006). Other factors recommended for consideration when determining the best alternative include cost, ease of use, maintenance requirements, and infection control issues (Crawford, Hicks, & Thompson, 2006).

In Lebanon, there has not been a study evaluating available, affordable, and accurate alternatives to mercury containing thermometers. Some private hospitals have replaced mercury thermometers with high-end electronic thermometers. The cost of non-mercury thermometers is a consideration in the phase-out of mercury in low-income healthcare settings. The Global Healthcare Waste Project is designed to demonstrate best practices for waste management in healthcare using two model facilities. Nabatieh Governmental Hospital (NGH) was one of the pilot facilities chosen and it expressed willingness to phase-out mercury containing devices. The other hospital had already chosen the non-mercury alternative device and thus was not feasible for the proposed study.

The aim of this study is to examine differences between the two non-mercury alternatives and nursing staff preferences based on the following primary attributes: costs, maintenance, lifespan, accuracy, and ease of use. Understanding the basis for the choices made by healthcare professionals and the suitability of a non-mercury alternative could inform the process of mercury phase-out planning for the healthcare sector in Lebanon.

2 LITERATURE REVIEW

Since the dawn of medicine, fever was regarded as a sign of abnormality and as a trigger for medical intervention (Pearce, 2002). The hypothalamus is the thermostat of the body, controlling the temperature of the inner milieu, which is better known as the "core temperature" (Crawford et al., 2006). Accurate measurement of this "core temperature" has always been essential for guiding medical treatment. Technology has improved a lot since the times of Hippocrates where the hand was used as the only means for detecting hyperthermia. In fact, the thermometer in its modern form appeared in 1866 when an English physicist interested in medicine, Thomas Allbut invented a 6-inch mercury thermometer (Pearce, 2002). Since then, the science of thermometry is in a continuous effort to find the single most accurate non-invasive clinical thermometer, the "gold standard".

Measuring core temperature through invasive means such as inserting a probe in the esophagus, pulmonary artery, nasopharynx or bladder is considered a standard practice in critical care settings. For the majority of the clinical settings, invasiveness is not a feasible or desirable option and so the clinician has to rely on less invasive means to estimate the core temperature. These include the oral cavity, axilla, and rectum; however recently the tympanic membrane and the forehead have been added. The accuracy of these sites in reflecting the core temperature is still a subject of clinical research, although the rectum has been cited in many studies as the most reliable (Bernard & Buist, 2003; El-Radhi & Barry, 2006; Lefrant, Muller, Coussaye, et al, 2003; Robinson, Seal, Spady, & Joffres, 1998).

The recent decades have witnessed the emergence of many technologies of thermometry. These include liquid-in-glass, chemical, electronic, and infrared thermometers (Crawford et al., 2006). Literature is still evolving regarding the suitability of different thermometers, since each type comes with its unique advantages and disadvantages. Crawford et al. (2006) cited many factors in determining the most appropriate thermometer for a healthcare setting. These include accuracy, ease of use, infection control, patient characteristics, maintenance requirements, and cost. The following review will present the different technologies of thermometry and their relevant advantages and disadvantages as reported in the literature.

2.1 Liquid-in-glass thermometers

This is the oldest technology, and it depends on the ability of certain liquids to expand with temperature. Assigning this expansion to a numerical scale provides a reflection of the temperature. This is done in a glass tube with a bulb containing the liquid at one end applied in contact with the tissue of the patient until thermal equilibrium is achieved (Crawford et al, 2006). Readings may take between 3 to 8 minutes depending on the site of measurement (Khorshid, Eser, Zaybak, &Yapucu, 2005). The liquid originally used was mercury but later Galinstan (gallium-indium-tin) was utilized. Mercury thermometers have been used in many studies as the standard thermometer (Davies, Kassab, Thrush & Smith, 1986; Jones, Kleber, &. Mahon 2003; Rosenthal & Leslie, 2006; Valle, Kildahl-Andersen, & Steinvoll, 1999); however there is a paucity of studies comparing mercury thermometers to more accurate thermometers whether in vivo or in vitro. In a study comparing the accuracy of an infrared tympanic thermometer to a mercury thermometer using a pulmonary artery sensor as a standard, mercury thermometers measurements were found to be 100% accurate (Amoateng-Adjepong, Del Mundo & Manthous, 1999). In addition to accuracy, mercury thermometers possess other advantages including no need of batteries and reliable performance regardless of environmental conditions (Crawford et al., 2006). On the other hand, mercury thermometers have long measurement times, are expensive as a result, and pose a risk to people and the environment. Measurement time has been implicated in many economic studies as the reason behind expensiveness of using mercury thermometers on the basis of personnel cost (David & Kelly, 1991; Sganga, Wallace, Kiehl, Irving, & Witter, 2000; Stavem, Saxholm, & Erikssen, 2000). The practice of changing the thermometer per patient also contributes to the cost difference. Mercury thermometers pose risks to patients when broken. Studies report several incidents of broken mercury thermometers inside patients' mouth or anus which directly exposes them to inhalation, ingestion, and absorption of mercury and injury from broken glass (Doreau, 1965; Shimoyama, Kaneko, & Horie, 1998; Yotsuyanagi, Yokoi, & Sawada, 1996). A broken mercury thermometer also poses risk to healthcare workers from vapors and is very pollutant to the environment (Sattler, 2002). This has led USA and other countries to ban their use (Crawford et al., 2006).

Galinstan thermometers are an environmentally-friendly alternative and have a comparable accuracy to mercury thermometers (Smith, 2003) and electronic thermometers (Lowe, 2009). Other than ecofriendliness, Galinstan thermometers possess the same profile as mercury thermometers regarding length of measurement and risk to patients in case of breakage. It is especially recommended in low-resource settings (Smith, 2003).

2.2 Chemical thermometers

This technology depends on the ability of some chemical material such as liquid crystal to change color at certain temperatures. Some chemical thermometers are single use, others are reusable but none can be used rectally. Their measurement time is better than liquid-in-glass thermometers; however they take longer than electronic and infrared thermometers (Crawford et al., 2006). Accuracy studies of chemical thermometers provide mixed evidence. Two studies in the pediatric and neonatal settings found comparable accuracy to mercury thermometers (Mauta,Vince, & Ripa, 2009; McKenzie, 2003). Another study found that chemical thermometers record higher temperatures than mercury thermometers (Qureshi, Khan, Chawla, et al., 2003). Farnell, Maxwell, Tan, Rhodes, & Philips (2003) compared tympanic to chemical thermometers using pulmonary artery sensor as the standard and found that the latter recorded erroneous readings. The main advantages of chemical thermometers are their safety and that they are not affected by surrounding environmental conditions (Crawford et al., 2006). They are recommended for low resource settings (Mauta et al., 2009).

2.3 Infrared thermometers

This technology depends on the ability of optical sensors to detect infrared emissions radiating from a surface (Crawford, Hicks, & Thompson, 2006). The thermometer’s infrared lens is positioned facing certain measurement sites such as the ear canal (tympanic membrane) or the forehead (temporal artery) to register the level of emissions and the thermometer then translates the data into a numerical reading. Literature about the accuracy of these thermometers is inconclusive albeit abundant.

Tympanic thermometers record the temperature of the tympanic membrane through inserting the measurement probe in the ear canal. Accuracy of reading is affected by certain factors, including the technique of use and patient’s condition. The ear canal should be straightened enough so that the thermometer’s lens would be detecting emissions from the eardrum not the surrounding cooler ear canal walls. Earwax and ear infections are some conditions that may affect measurement accuracy. Tympanic thermometers have been extensively compared to mercury thermometers at different sites of measurement. When compared to mercury thermometers used rectally, tympanic thermometers’ readings were found to deviate anywhere between -0.5 °C up to -1.4 °C in febrile patients (Valle et al., 1999). Jensen, Madsen, and Løssl (2000) also found clinically significant differences between readings of tympanic thermometer and mercury thermometer used rectally. When compared to mercury thermometers used orally, tympanic thermometers had sensitivity as low as 60% in detecting fever (Prentice & Moreland, 1999). When compared to a pulmonary artery sensor, accuracy of readings of a tympanic thermometer ranged between 50 – 98 % depending on the level of education of the user, suggesting a human factor (Amoateng-Adjepong et al., 1999; Farnell et al. 2003). This contrasts an earlier study by Rostello, Crawford, and Terndrup (1996) who reported that tympanic thermometer measurements reflected accurately and predictably core body temperature when compared to pulmonary artery sensor. Significant differences were also found between tympanic thermometers and electronic thermometers used orally (Irvin, 1999; Spitzer, 2008). In a systemic review by Dodd and colleagues (2006), it was found that tympanic thermometers would fail in detecting fever in 30-40% of children. Albeit unsupported accuracy, tympanic thermometers possess unique desirable features including short reading time and easy accessibility of measuring site (Crawford et al., 2006). Cost savings has been reported in some economic studies mainly because of saved personnel time (David & Kelly, 1991; Stavem et al., 2000). Their high purchase cost and difficult usage technique is also an issue to consider when planning hospital wide use.

Temporal thermometers record temperature through detecting the infrared emissions from the skin above the temporal artery. The thermometer must be swept from the middle of the forehead towards the periphery adjacent to the eyebrow in a specified period of time based on the manufacturer's recommendation. Temporal thermometers have been compared to various arrays of measurement methods. In comparison to invasive methods such as pulmonary artery or esophageal sensors, temporal thermometer readings were significantly variable and unreliable, especially during periods of increasing body temperature (Hebbar et al., 2005; Kistemaker et al., 2006). When compared to mercury thermometers used axillary, temporal thermometer readings were different by a mean of 0.07°C (Rosenthal & Leslie, 2006). Other studies compared temporal to tympanic thermometers using digital thermometry at the rectal site as the standard. The results showed that both types of thermometers were unreliable in detecting fever, with each study finding a slightly better performance in one or the other thermometer (Greenes & Fleisher, 2001; Paes et al., 2010). The accuracy of temporal thermometer measurement depends highly on the expertise of the user and its performance is affected by perspiration, skin lotions, and environmental conditions (i.e. room temperature). Its main advantages are short measurement times and easy accessibility of the measurement site (Crawford et al., 2006). Its no-touch technique has been implicated in the decreased risk of nosocomial infections. From the economic perspective, tympanic thermometers are expensive and need a lot of training to master; however this may be offset by the saved personnel time during measurement (David & Kelly, 1991; Stavem et al., 2000).

2.4 Electronic thermometers

This technology depends on a thermistor, which is an electrical resistor whose resistance is sensitive to the surrounding temperature. It comes in two forms, one is the size of a phone handset and is known as electronic thermometer and the other is the size of a ballpoint pen and is commonly known as the compact electronic thermometer (Crawford et al., 2006). Sites of measurement include the axilla, rectum, and oral cavity. Literature about accuracy of this type of thermometers gives a better profile than other technologies. Studies comparing electronic and compact electronic thermometers to mercury thermometers found a mean difference in readings ranging between 0.0 °C to 0.05°C especially when used rectally (Davies et al., 1986; Jensen et al., 2000; Rosenthal & Leslie, 2006; Shanks, Lambourne, Morton, & Sanford, 1983; Valle et al., 1999;). One study found higher readings compared to mercury thermometers (Jones et al., 2003). Compared to tympanic thermometers, electronic thermometers were found more accurate and reliable and have higher sensitivity for detecting fever (Jensen et al., 2000; Prentice & Moreland, 1999; Valle et al., 1999). Few studies compared electronic to compact electronic thermometers regarding accuracy. Sganga and colleagues (2000) found that compact electronic thermometers provide closer measurements to mercury thermometers than electronic thermometers. The main advantages of this type of thermometers are ease of use and fast measurement time; while their main disadvantages are that they are affected by electromagnetic waves and the environment's temperature (Crawford, Hicks, & Thompson, 2006). Electronic thermometers have been implicated in some studies as means for transmitting infections between patients (Brooks et al., 1992; Livornese et al., 1992); however, a randomized crossover study showed no difference in the rate of nosocomial infections when compared to disposable thermometers (Jernigan, Siegman-Igra, Guerrant, & Farr, 1998). From the economic perspective, the cost range is wide between electronic and compact electronic; however, saved nurse's time is an important compensatory factor compared to less expensive technologies (Stronge & Newton, 1980).

As noted in the above review, the literature about thermometry is still incomprehensive and inconclusive and is difficult for meta-analysis mainly because studies target different patient populations and utilize a variety of devices (Crawford et al., 2006). Overall, electronic thermometers have the widest support as reliable, accurate, and safe alternatives to mercury thermometers. They can be used at different measurement sites and are widely available. This study will evaluate different technologies of thermometers available in the Lebanese market. Comparison will be done based on the following attributes including cost, accuracy, maintenance, life span, and ease of use. The ultimate aim of this project is to evaluate available thermometers and recommend the better alternative for the healthcare sector in Lebanon.

The objectives of the study are:

1. To determine the available thermometry technologies available in the Lebanese market and their cost effectiveness for a model healthcare facility.
2. To determine the suitability of use of two alternative thermometers in a hospital setting based on differences in their essential characteristics and preferences of healthcare professional staff.

3 DESIGN

3.1 Methodology

This project is a descriptive correlational study composed of three components. A mixed methodology will be used to evaluate the two non-mercury thermometers. The discussion of the methodology will be done separately for each component.

The aim of the first component was to determine the two electronic thermometers to be evaluated. This was done based on the market availability, nursing preferences, cost, maintenance, and life span of the thermometers. The different types and brands of thermometers available in the market were identified from the list of vendors of medical equipments. The characteristics of the identified thermometers were collected from the manufacturer's manuals. A questionnaire assessing nursing administrators' preferences regarding significant criteria of the electronic thermometers was utilized and followed with an economical evaluation to determine the cost effectiveness of each alternative type of thermometer. Finally maintenance requirements and thermometers' life span were used to fine tune the evaluation. This component concluded with the selection of the two alternative thermometers for further evaluation.

The aim of the second component was to evaluate the two alternative thermometers regarding accuracy and ease of use using a clinical and laboratory approach, respectively. The accuracy part was conducted on five clinical areas including an adult medical surgical, obstetrics, pediatrics, intensive care, and neonatal intensive care units in the chosen hospital to determine correlation between the readings of the two alternative thermometers. The output of this evaluation was a determination of whether or not there are statistically significant differences between the values measured by the two thermometers. Ease of use was evaluated in a controlled setting through letting ten healthcare staff (practical nurses) measure temperatures of a volunteering subject while recording number of steps and time needed to accomplish the procedure. The output of this evaluation was a determination of which of the two thermometers was easier to use (i.e. fewer steps and shorter time).

The aim of the third component was to evaluate nursing staff's opinions regarding life span, accuracy, and ease of use of the two thermometers in addition to any other comments they had that might help in evaluating the two thermometers. Five practical nurses used the two types of thermometers for five days and were then asked to rank and comment on each thermometer based on the aforementioned attributes. The output of this component was an evaluation of the two thermometers based on perceived characteristics.

3.2 Ethical considerations

The study was approved by the Institutional Review Board (IRB) of the American University of Beirut and the medical director of NGH. For the accuracy study, each patient had two temperature measurements using each thermometer. Temperature was taken from the site that was usually used in that ward. Efforts were done to include different patients as much as possible to equitably distribute the burdens of research. In case of insufficient patient population, measurements were repeated on the same patient so as not to exceed two sets of measurements per nursing work shift (i.e. 8-12 hours). The patients were recruited by the assigned staff in a convenience sampling approach from the pool of patients admitted to the ward. Informed consents were obtained from the patients/legal guardian/parent on each measurement event and an assent and parent consent/permission were obtained from the child and his/her parent when applicable. Each measurement event was assigned a number without any reference to the identity of the patient.

Non-mercury thermometers, whether they use electronic or infra-red technology, pose low risk to the patients or healthcare workers and are generally considered safe. Some studies however have identified electronic thermometers as means for transmitting infections between patients (Brooks et al., 1992; Livornese et al., 1992). This risk was minimized by using sterile probe covers for each thermometer. Moreover, each thermometer was wiped with a disinfectant between patients to decrease the risk of contamination. For standardization purposes, a protocol for taking patients' temperatures (Appendix A) was utilized.

For the evaluation of the ease of use, temperature measurements were taken on a volunteer who was a practical nurse. His name was suggested by the nursing director and a written consent was obtained from him. Ten staff nurses took six temperature measurements each, three by using each thermometer on the volunteer. Measurements were taken orally to decrease any possible discomfort for the volunteer. There was no risk of infection since the thermometers were not used before.

For the comparison of the thermometers from the healthcare staff’s perspective, each staff from each ward used the two thermometers in an alternative matter thus each patient had one temperature reading at a time. An oral consent was obtained from each patient. A copy of the script of the oral consent was given to each patient.

4 COMPONENT1: SELECTION OF THE TWO-NON-MERCURY THERMOMETERS

There is a variety of thermometers available in the Lebanese market from different types and brands. To determine available types and brands, vendors of medical devices in the Lebanese market were contacted to elicit quotations and specifications. For selection of the two non-mercury thermometers, alternatives were evaluated based on four primary attributes: nursing leadership preferences, cost, maintenance, and life span.

4.1 Market survey of mercury-free thermometers

A list of vendors of medical equipment was formed after consulting the internet and the Lebanese telephone directory. Ten vendors were identified, scattered geographically over the different Lebanese territories. These suppliers of mercury-free thermometers were contacted to identify the different types, brands, specifications and prices of thermometers available. All suppliers responded. The survey resulted in identifying 10 brands of compact electronic thermometers, one single brand of electronic thermometers, five brands of infrared tympanic thermometers and three brands of infrared temporal thermometers. The specifications of different types and brands of thermometers are summarized in Appendix B.

4.2 Nursing Leadership Preferences

To determine the selected alternative thermometers, nursing preferences had to be factored in. For this purpose, a group meeting was conducted with the Nursing Administration at NGH to introduce the objectives and methodology of the comparative study, the features of the different types of thermometers available on the Lebanese market, and to nominate hospital departments and personnel to be involved in the study. Their preferences were assessed through a questionnaire (Appendix C) distributed at the adjournment of the meeting.

A survey questionnaire including the different characteristics of mercury-free thermometers was distributed to ten nurse managers to assess their preferences for the selection of suitable thermometers. The questionnaire was developed based on the different specifications of each type and brand of thermometers identified during the market survey. It included seven multiple-choice questions and the option of adding other desired features of the alternative thermometers. The questionnaire was supplemented with a cover letter about the study and was handed to the nurse managers in a sealable envelope. The nurse managers were given one week to return the filled questionnaire to a designated location in the hospital specified in the cover letter. Their response was considered as an implied consent. The desired features were used as criteria for determining the two alternative thermometers. The results of the survey are presented in Table 1 and Table 2.

Eight nurse managers responded to the questionnaire. Analysis of preferred criteria showed that the selected thermometer should display the result digitally, thus liquid-in-glass and chemical (phase change) thermometers were dropped from the list of choices. The thermometer had to have the ability to measure the temperature from different sites and convert it to core body temperature, thus infrared thermometers being designed to measure temperature at a single site were left out of the choices. As a result, the alternative thermometer had to be electronic or compact electronic.

Table 1: Criteria of Alternative Thermometers as Rated by Eight Nurse Managers

Criteria	Level of Importance		
	Very Important	Somewhat Important	Not Important
Digital display of result instead of any other indicator (i.e. chemical or visual)	100%	0	0
Alarm when peak temperature is reached	100%	0	0
Disposable probe covers instead of regular disinfection of probe tip	100%	0	0
Customized colors to distinguish between oral, rectal, and axillary use	100%	0	0
Warning when temperature is out of range	75%	25%	0
Flexible probe tip	37.5%	62.5%	0
Memory function	12.5%	50%	37.5%

Table 2: Leadership's Qualitative Comments Regarding Specifications of Alternative Thermometers

Comments	Frequency
Automatic calculation of the core temperature result from different sites	3
The cost is important	1
Temperature to be in Celsius	1
Accuracy between different sites	1
It is important to have a rechargeable battery of good quality	1
To be waterproof and shock proof	1

Noting that only one brand of electronic thermometers was identified; the compact electronic thermometers were ranked by the researchers based on the criteria selected by the nursing administration at NGH and the standards of manufacturing met as shown in Table 3. A thermometer meeting a criterion was given a grade of 1 and then the grades were added up to give each thermometer a total score. As a result, MT 200 (Microlife, Switzerland) scored the highest among compact electronic thermometers and was the best choice based on nursing administration's preferences.

Table 3: Ranking of Compact Electronic Thermometers Based on Criteria Selected by Nursing Staff

Criteria Brand	Peak temperature alarm	Customized colors for different sites	Warning when temperature out of range	Meet standards	Flexible probe tip	Start-up self-check	Memory function	Total Score
MT 200 (Microlife)	X		X	X	X	X	X	6
SpeedRead V911 (Vicks)	X		X	?		X	X	4
ComfortFlex V965F (Vicks)	X		X			X	X	4
MT16 F1 (Microlife)	X			X		X	X	4
Flex Temp smart MC-343F-E (Omron)	X			X	X		X	4
Eco Temp Smart MC-341-E (Omron)	X			X		X	X	4
GIMA 25560	X	X		?			X	3

DT-11	X		X		X	3
GT004-230 (Greet med-China)	X	X	?	X		3
GT004-204 (Greet med-China)	X	X				2

4.3 Comparative costing of thermometers

4.3.1 Types of costs

A cost comparison between the identified types of thermometers was conducted. The aim of that analysis was to determine the cost effectiveness of each type of thermometers. The costing model was adopted from the study done by Crawford et al. (2006). The types of costs included in the analysis are thermometer costs, disposable supply costs, personnel costs, and equipment service costs as recommended by Alexander and Kelly (1991). Costs and their calculation methods are summarized in Appendix D.

4.3.2 Data collected from the hospital

Data collected from the hospital in relation to personnel cost and number of in-patients and outpatients are presented in Appendix D.

4.3.3 Assumptions

It was assumed that the average number of temperature measurements per inpatient per day is 3 times (one time per an 8-hour nursing shift) and per outpatient per visit is once.

Based on this, it is estimated that the number of temperature measurements taken annually for inpatients = number of beds x average occupancy rate x estimated number of temperature measurements per patient per day (3 times) x 365 =103 beds x 0.9 x 3 x 365= 101,507 measurements and the number of temperature measurements taken annually for outpatients = average outpatients per day x estimated number of temperature measurements per patient per visit (once) x 365= 133 x 1 x 365= 48,545 measurements. Thus, the total Number of temperature measurements annually= 150,052 measurements.

The price of thermometers was considered as the average cost of the different brands of each type of thermometers (compact electronic, electronics, etc…) obtained from national vendors. The cost of batteries was considered as the average cost of different batteries used in the various brands of the different types of thermometers adjusted to the number of batteries needed by each thermometer's brand. The cost of mercury cleanup includes cost of spill kits and nurses' time for cleanup. A simple spill kit is about USD 100 including personal protective equipment (PPE). It is assumed that 10 spills occur per year x USD 100 per spill kit = USD 1,000. In addition, it is estimated that the time for mercury cleanup is 1 hour per spill for a trained nurse.

The calibration cost necessitated the estimation of calibration time needed for each thermometry method. Since there is no such data available in the literature, this had to be done through evaluating the steps of the calibration method and the measurement time for each thermometry method. The measurement time was considered as the average time needed to calibrate the various brands of each type of thermometers as mentioned in their technical manuals. The calculations for estimating the calibration time are summarized in Appendix E.

Concerning the calibration equipment, for the compact electronic thermometer a 5L beaker or larger, lab jack, insulation, hot plate and magnetic stirrer, stand and clamps, traceable precision reference thermometer (as the standard) would be needed. The total cost for these is estimated at USD 990. For tympanic and temporal the Welch Allyn/Braun calibration tester could be used and it is estimated at about USD 1000.

Table 4 presents the assumed number of thermometers that will be needed per type as well as details on each thermometer's needs for consumables, batteries, calibration and replacement based on manufacturers' manuals.

Table 4: Assumptions of number of needed equipment and services

Type of thermometer	Electronic	Compact electronic	Infrared tympanic	Infrared temporal	Mercury
Number of thermometers purchased	One per 10 beds (1 rectal probe per department)	Two per hospital bed (one for oral/axillary use and one for rectal use)	One per 10 beds	One per 10 beds	One per patient
Consumables	Probe covers	Probe covers/ alcohol swabs	Probe covers	Probe covers	Alcohol swabs
Battery replacement	Yes	Yes	Yes	Yes	-

Useful life of battery (measurements)[1]	6000	4997	2400	8125	-
Estimated thermometers needed for replacement annually (%)	0	10	0	0	4.3%[2]
Calibration frequency	Every 6 month	Every 2 years	Every year	Every 6 month	-
Calibration time (min.)	27	24.6	25.4	25.4	-
Measurement time (s)	9.5	39	3	2	320

The measurement time for the different compact electronic thermometers' brands as reported by the manufacturers is listed in Appendix D

4.3.4 Cost comparison of the different types of thermometers

Table 5 presents a comparison of the different types of thermometers. Costs are categorized in investment costs and running costs. Investment costs include cost of thermometers and accessories while running costs include cost of probe covers, batteries, alcohol wipes, maintenance, calibration, personnel, and mercury spill handling. Maintenance was estimated at 5% of purchase cost as in Crawford et al. (2006) and compact electronic thermometers were assumed to be thrown when defected.

Table 5: Comparative cost of different types of thermometers in USD

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[1] This is derived from the average number of measurements per battery reported in thermometer's manual

[2] This number was derived from comparing the quantity of mercury thermometers used at NGH by the number of patients admitted to the hospital. The difference amounted to 4.3%. (Baseline assessment)

Type of thermometers	Electronic	Compact electronic	Infrared tympanic	Infrared temporal	Mercury
Investment cost per unit					
Unit Price [3]	395	6.65	120.62	293.7	0.4
Accessories[4]	127				
Running cost per unit					
Probe covers	0.05	0.07	0.2	0.22	
Batteries [5]	2.16	1.06	2.15	2.5	
Cleaning (alcohol wipes)		0.009			0.009
Maintenance cost[6]	19.75		6.03	14.68	
Total investment cost					
Total cost of thermometers	7,505	1,729	2,292	5,580	23,092
Total cost of (accessories)	1,524				
Calibration equipment	1,000	990	1000	1000	
Total investment cost	10,029	2,719	3,292	6,580	23,092
Total annual running cost					
Replacement		172.90			992.97
Batteries	54.02	31.83	134.42	46.17	-
Alcohol swabs		1,350.47			1,350.00
Probe covers	7,502.60	10,503.64	30,010.40	33,011.44	
Maintenance	375.25		114.59	279.02	
Calibration	48.43	150.95	22.78	45.56	
Nurses' time	826.79	3,394.18	261.09	174.06	27,849.65
Mercury spill kit					1,000.00
Personnel's time for mercury spill cleanup					20.88

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[3] Price is based on average of quotations received from vendors

[4] rectal probes

[5] costs of batteries adjusted to the number of batteries needed by each thermometer brand

[6] repair cost estimated at 5% of purchase cost

Total annual running cost	8,807.08	15,603.96	30,543.28	33,556.24	31,213.50
Total cost at year one	18,836.08	18,322.96	33,835.06	40,136.54	54,305.90

This cost comparison showed that mercury thermometers had the highest investment cost while compact electronic thermometers had the least investment costs. Electronic thermometers had the lowest annual running cost while infrared temporal thermometers had the highest annual running cost. Mercury thermometers are the least cost effective among other thermometers because of per patient utilization which skyrockets investment cost, as well as the high annual running cost. Although electronic thermometers may cost slightly more than compact electronic thermometers at year one, they tend to be the most cost effective on the long run because of the low running cost. These findings echo Sganga and colleagues' (2000) results regarding mercury thermometers' cost ineffectiveness. Short measurement time has been identified as a crucial element in the cost effectiveness of high tech thermometry including electronic thermometers because of its impact on personnel cost (Stavem et al., 2000).

Since the total annual costs for compact electronic thermometers are greater than that of the electronic, a more thorough investigation was done to investigate if using one compact electronic thermometer per patient would be more cost effective than multiple-patient use due to the saving of probe covers' cost. The results came up favoring the multiple-patient use approach by far. Calculations summarized in Table 6.

Table 6: Cost comparison of single versus multiple patient use of compact electronic thermometers in USD

Mode of use	Single	Multiple
Investment cost per unit		
Unit price	6.65	6.65
Running cost per unit		
Probe covers	-	0.07
Batteries	-	1.06
Alcohol swab	0.009	0.009
Maintenance	-	-
Total investment cost		
Total price of thermometers	38,3911	1,729
Calibration equipment	990	990
Total investment cost	38,4901	2,719
Total annual running cost		
Replacement	-	172.9
Batteries	-	31.83
Alcohol swab	1,350.47	1,350.47
Probe covers	-	10,503.6
Maintenance	-	-
Calibration	-	49
Nurses’ time	3,394.18	3,394.18
Total annual running cost	4,744.64	15,502
Total cost at year one	389,646	18,221

To evaluate the ten brands of compact electronic thermometers available, a cost comparison was done. The costing model and the assumptions resemble those described above. The results are summarized in Table 7. The most cost effective brand was MT200 (Microlife, Switzerland) especially after factoring in the cost of nurses’ time.

Table 7: Comparative costing of different brands of compact electronic thermometers in USD

Type of thermometer	Flex Temp smart MC-343F-E (Omron)	Eco Temp Smart MC-341-E (Omron)	GIMA 25560	DT-11	SpeedRead V911 (Vicks)	ComfortFlex V965F (Vicks)	MT16 F1 (Microlife)	MT 200 (Microlife)	GT004-230 (Greet med-China)	GT004-204 (Greet med-China)
Investment cost per unit										
Unit Price	5.4	3.68	7.1	3.3	13	16	3.5	10	2.5	2
Running cost per unit										
Probe covers	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Batteries	1.06	0.75	1.06	0.75	2	2	0.75	0.75	0.75	0.75
Alcohol swabs	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009
Total investment cost										
Total cost of thermometers	1,404	956.8	1,846	858	3,380	4,160	910	2,600	650	520
Calibration equipment	990	990	990	990	990	990	990	990	990	990
Total investment cost	2,394	1,946.8	2,836	1,848	4,370	5,150	1,900	3,590	1,640	1,510
Total annual running cost										
Replacement	140.4	95.68	184.6	85.8	338	416	91	260	65	52
Batteries	31.83	22.52	31.83	22.52	60.06	60.06	22.52	22.52	22.52	22.52
Alcohol swabs	1,350.47	1,350.47	1,350.47	1,350.47	1,350.47	1,350.47	1,350.47	1,350.47	1,350.47	1,350.47
Probe covers	10,503.64	10,503.64	10,503.6	10,503.6	10,503.64	10,503.6	10,503.64	10,503.64	10,503.6	10,503.6

Calibration	52.92	52.92	176.41	235.21	32.34	32.34	176.41	29.40	235.21	114.67
Nurses' time	1,566.54	1,566.54	5,221.81	6,962.41	957.33	957.33	5,221.81	870.30	6,962.41	3,394.18
Total annual running cost	13,645.80	13,591.78	17,468.76	19,160.06	13,241.84	13,319.8	17,365.85	13,036.33	19,139.26	15,437.47
Total cost at year one	16,039.80	15,538.58	20,304.76	21,008.06	17,611.84	18,469.8	19,265.85	16,626.33	20,779.26	16,947.47

1 for brands with no specified battery life, the average battery life of all compact electronic thermometer brands was used

4.3.5 Limitations

There are some costs that were not included in this costing model due to inability to assign to them a monetary value and partly because they are outside the scope of this project. These include indirect personnel costs (e.g. cost of training and changing policies), depreciation cost, cost of treatment and disposal of mercury waste resulting from mercury spills, and legal and environmental costs of continuing the use of mercury thermometers.

4.4 Maintenance and life span

Maintenance requirements were retrieved from manufacturers' manuals. Suretemp Plus 690 (Welch Allyn – USA) is recommended to be checked regularly every 6 months. This was discussed with the hospital's biomedical engineer and it was found reasonable. The method for checking would be a calibration test using the Suretemp Plus calibration key. MT200 (Microlife, Switzerland) is recommended to be checked regularly every two years or after a mechanical impact such as being dropped. This was discussed with the biomedical engineer and it was agreed that an accuracy test using a water bath would be used for checking. Compact electronic thermometers that show inaccurate readings will be replaced with new ones. The reason for this is that it's more cost effective to buy a new compact digital thermometer than to attempt fixing a broken one. This was accounted for in the cost comparison analysis as the replacement of ten percent of thermometers annually.

Life span data was not found for any thermometer brand. Manufacturers do not reveal such data and there is no evidence that it is being collected. Only one study was found in the literature that accounted for life span and depreciation in its economic analysis (Stavem et al., 2000) and the source of their data was not mentioned. The thermometer considered in that study was a tympanic thermometer and thus the estimated life span was irrelevant to this study. A Lebanese medical center utilizing Suretemp Plus 690 (Welch Allyn – USA) for the past decade was consulted regarding the life span of this brand of thermometers, but this data was not collected regularly. Crawford et al. (2006) assumed a 10% replacement rate for compact electronic thermometers thus if considered collectively, the combined life span of electronic thermometers would be 10 years with an annual depreciation rate of 10%. With such paucity of reported information, life span was further evaluated based on the perceptions of healthcare personnel in component 3.

4.5 Conclusion

Based on this comparative evaluation of thermometers, compact electronic and electronic thermometers appear to be the most cost effective types. There is only one brand of electronic thermometers available in the Lebanese market which is the Suretemp Plus 690 (Welch Allyn – USA) thus there was no need for an evaluation among this type of thermometers. Among the compact electronic thermometers brands, the MT200 (Microlife, Switzerland) was the most favorable for further evaluation in this project. It was the most cost effective and had the highest score for preferable criteria.

5 COMPONENT 2: EVALUATING ACCURACY AND EASE OF USE OF THE TWO ALTERNATIVE THERMOMETERS

5.1 Accuracy

Electronic thermometers including the compact type have a set of requirements for performance as specified in international standards such as the American Society for Testing and Material (ASTM) E825 (1998), ASTM E1104 (1998), ASTM E1112 (2000), British Standard European Norm (BS EN) 12470-3 (2000), and BS EN 12470-4 (2000), which specify the maximum permissible error of measurement, among other requirements. Lebanon adopted the European standards (i.e. BS EN 12470-3/4) in 2008 (NL EN 12470-3, 2008; NL EN 12470-4, 2008). The maximum permissible error according to these standards ranges between 0.1 – 0.3 °C according to the measuring temperature range and the ambient temperature range. These standards recommend the water bath method for verification of accuracy. This method includes taking temperature measurements of a water basin at different temperatures and comparing them to a calibrated reference thermometer. The manufacturer of the compact electronic thermometer MT200 (Microlife, Switzerland) claims satisfaction of ASTM E1112 (2000) and BS EN 12470-3 (2000) standards and thus no laboratory evaluation of accuracy was conducted. The manufacturer of the electronic thermometer Suretemp Plus 690 (Welch Allyn – USA) does not claim satisfaction of any of these standards, thus the hospital's biomedical engineer was consulted regarding the feasibility of doing a water bath study. He advised that Welch Allyn provides a calibration machine (Welch Allyn Calibration Tester Modell 9600/B) that mimics the water bath experiment. Calibration is done through setting the machine at the desired temperature, waiting for the temperature to be attained, and then inserting the thermometer’s probe in a hole at the top of the calibration machine for measurement. The Suretemp Plus 690 (Welch Allyn – USA) thermometers were calibrated using this method and the readings of all the thermometers met the maximum permissible error specified in the international standards.

5.1.1 Statistical Analysis

Results were analyzed using two approaches, paired-samples t-test and Bland-Altman analysis. Paired-samples t-test was used since the population was found to be normally distributed for age and temperature readings and post-hoc power analysis showed enough sample size to perform the test. The objective of this approach was to determine if there is a statistically significant difference between the readings of the two thermometers and the degree of correlation between the two readings. Bland & Altman (1986) proposed a statistical technique to study the agreement between two clinical measurement technologies when the true value of what is being measured is unknown. If the level of agreement between the two technologies is sufficient, in other words the difference between the readings is not clinically significant, the two technologies could be used interchangeably. The range of difference that was considered to be clinically non-significant was ±0.5°C as recommended by other investigators (Kimberger, Cohen, Illievich, & Lenhardt, 2007; Moran et al., 2007; Suleman, Doufas, Akca, Ducharme, & Sessler, 2002). The objective of this approach is to determine if there is a clinically significant difference between the values measured by the two thermometers.

5.1.2 Results

5.1.2.a Demographical data

The sample included 150 readings taken on patients admitted to five clinical units namely an adult medical/surgical unit, obstetrics and gynecology unit, adult intensive care unit, pediatrics unit, and neonatal intensive care unit. Ninety three readings were taken on female patients (62%). Sixty two percent of patients were between 1 month and 60 years of age (Table 8). Forty percent of measurements were taken orally and another 40% were taken axillary, while the rest of measurements were taken rectally. Table 9 and table 10 present the sample size, gender, and age of patients by site of measurement and hospital department respectively.

Table 8: Demographic characteristics of the Patient Population (N=150)

Variable	Frequency (%)
Gender: Female	93 (62)
Age	
≤ 1 month	30 (20)
1 month – 18 years	32 (21)
19 years – 60 years	61 (41)
≥60 years	27 (18)

Table 9: Distribution of Patient Characteristics by Measurement Site (N = 150)

Measurement site	Sample size[7] (%)	Gender: Female (%)	Age mean (SD)
Oral	60 (40)	49 (81.7)	39.41 (19)
Axillary	60 (40)	27 (45)	34.44 (31.55)
Rectal	30 (20)	17 (56.7)	1.63 (2.17)[8]

Table 10: Distribution of Patient Characteristics by Hospital Department

Hospital department	Sample size[7] (%)	Gender: Female (%)	Age mean (SD)
Adult Medical/Surgical	30 (20)	19 (63.3)	51.66 (19.72)
Obstetrics/Gynecology	30 (20)	30 (100)	27.16 (5.96)
Adult Intensive Care Unit	30 (20)	15 (50)	61.43 (21.99)
Pediatrics	30 (20)	12 (40)	7.45 (5.86)
Neonatal intensive Care	30 (20)	17 (56.7)	1.63 (2.17)[8]

5.1.2.b Evaluation of the accuracy of two thermometers

Analysis was carried for the total sample, among measurement sites, and among hospital departments (Table 11). Paired-sample t-test showed a statistically significant difference between the readings of the compact electronic and electronic thermometers for the total sample (*p* <0.001). The Pearson correlation coefficient (R) was 0.647 (*p*<0.001). Considering that a correlation coefficient of 0.8 as an acceptable and strong correlation (Chan, 2003), this study found a weak correlation between the readings of the two thermometers. The mean difference between the readings was 0.45 ± 0.49°C. Agreement between the readings of the two thermometers using Bland-Altman analysis is illustrated in figure 1. Limits of agreement (LoA) calculated as mean difference between measurements ± 2 standard deviations showed a range of differences [-0.534, 1.434] that is clinically significant (i.e. greater than ± 0.5°C), thus indicating poor agreement. More precisely, around one third (31.3%) of measurements differed significantly from the clinical point of view, with the compact electronic thermometer registering a higher temperature 84.6% of the time. Seven measurements by the compact electronic

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[7] All values are frequencies and percentages in readings

[8] All values are frequencies and percentages in day

thermometer (4.6%) were for febrile subjects (i.e. temperature ≥38.3°C), three of them were also registered by the electronic thermometer as febrile.

Figure 1: Bland-Altman plot of difference for the whole sample

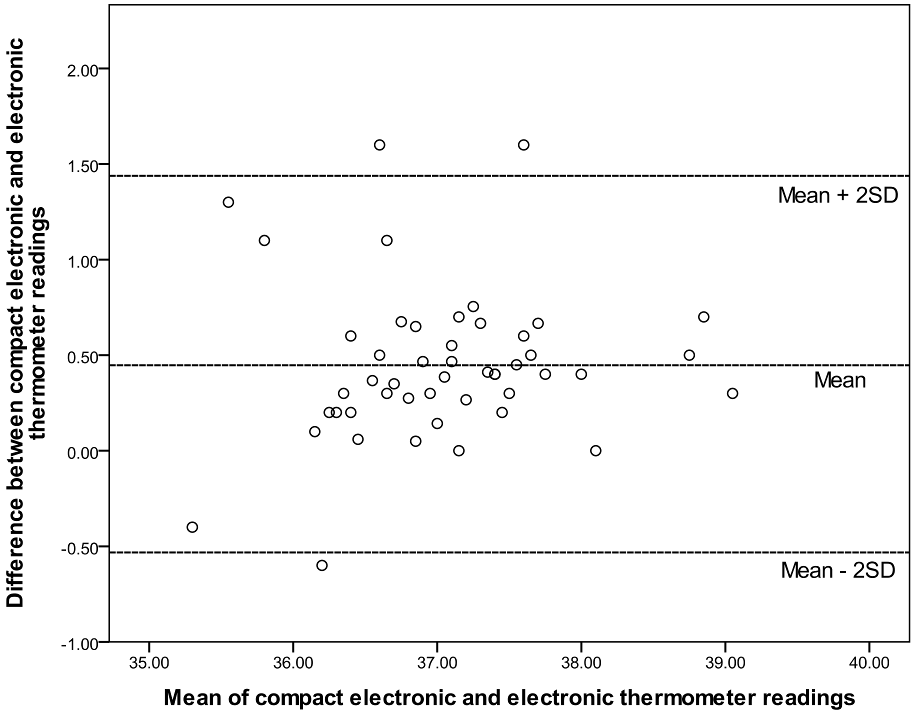


Table 11: Comparison of the measurements of two thermometers for the total sample, per measurement site, and hospital department

	Total sample	Temperature taking site			Hospital Department				
		Oral	Axillary	Rectal	Medical/ Surgical	Obstetrics	ICU	Pediatrics	ICN
Sample Size (readings)	150	60	60	30	30	30	30	30	30
Number of readings higher with compact electronic (%)	127 (84.6)	45(75)	59(98.3)	23(76.6)	22(73.3)	23(76.6)	30(100)	29(96.6)	23(76.6)
Number of identical readings (%)	7 (4.6)	5 (8.3)	1(1.6)	1(3.3)	3(10)	2(6.6)	0	1(3.3)	1(3.3)
Number of lower readings (%)	16 (10.6)	10 (16.6)	0	6(20)	5(16.6)	5(16.6)	0	0	6(20)
Number with 0.5°C or more difference (%)	45 (31.3)	8 (13.3)	33(55)	6(20)	2(6.6)	6(20)	16(53.3)	17(56.6)	6(20)
Mean difference of readings (SD*)	0.45 (0.49)	0.2 (0.35)	0.77 (0.47)	0.31 (0.41)	0.17 (0.25)	0.23 (0.43)	0.79 (0.52)	0.75 (0.42)	0.31 (0.41)
Range of difference of readings	-0.7 to +2.2	-0.7 to +1.4	0 to +2.2	-0.4 to +1.3	-0.7 to +0.6	-0.6 to +1.4	+0.3 to +2.2	0 to 1.6	-0.4 to +1.3
95% confidence interval for mean difference	0.373-0.532	0.112-0.294	0.652-0.897	0.155-0.464	0.802-0.273	0.069-0.390	0.598-0.988	0.596-0.917	0.155-0.464
t-test	11.272	4.466	12.647	4.111	3.747	2.929	8.316	9.646	4.111
P value	□ 0.001	□ 0.001	□ 0.001	□ 0.001	□ 0.001	□ 0.001	□ 0.001	□ 0.001	□ 0.001
Correlation coefficient (Pearson R)	0.647	0.71	0.654	0.817	0.748	0.694	0.583	0.724	0.817

Legend: SD = Standard Deviation

Paired-sample t-test showed a statistically significant difference between the readings of the compact electronic and electronic thermometers for the oral, axillary, and rectal sites ($p < 0.001$). The Pearson correlation coefficients (R) were respectively 0.710, 0.654, and 0.817 ($p < 0.001$). Considering that a correlation coefficient of 0.8 as an acceptable and strong correlation (Chan, 2003), measurements correlated strongly for the rectal site only. The mean differences between the readings were 0.2 ± 0.35°C for the oral site, 0.77 ± 0.47°C for the axillary site, and 0.31 ± 0.41°C for the rectal site. Agreement between the readings of the two thermometers using Bland-Altman analysis is illustrated in figures 2, 3 and 4. Limits of agreement (LoA) for the oral [-0.505, 0.905], axillary [-0.194, 1.724], and rectal [-0.510, 1.136] sites showed a range of differences that is clinically significant (i.e. greater than ± 0.5°C) thus indicating poor agreement. More precisely, 13.3%, 55%, and 20% of oral, axillary, and rectal measurements respectively differed significantly from the clinical point of view with the compact electronic thermometer registering a higher temperature between 75% and 98.3% of the time.

Figure 2: Bland-Altman plot of difference for the oral site

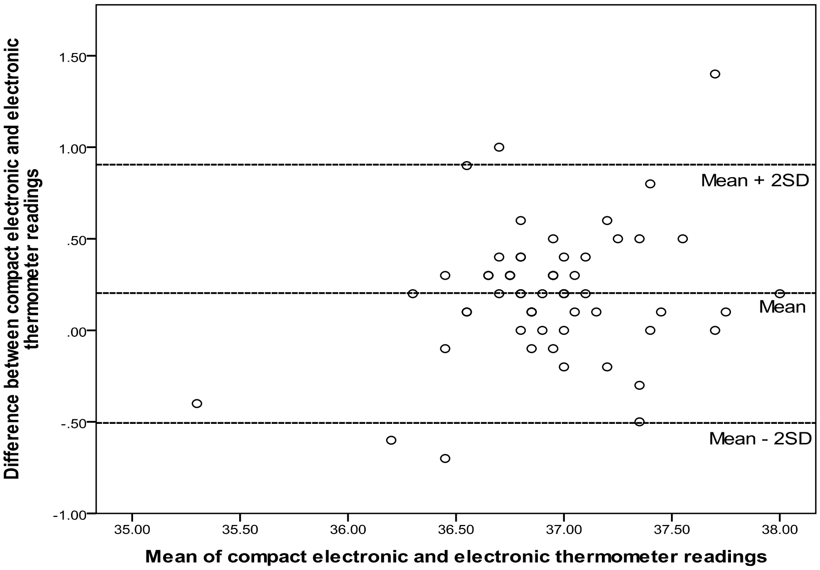


Figure 3: Bland- Altman plot of difference for the axillary site

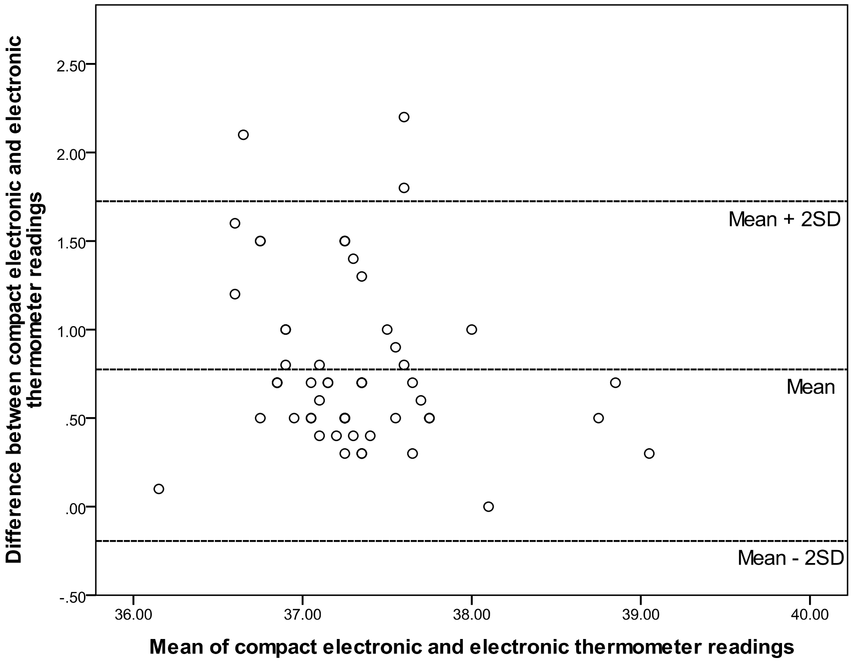
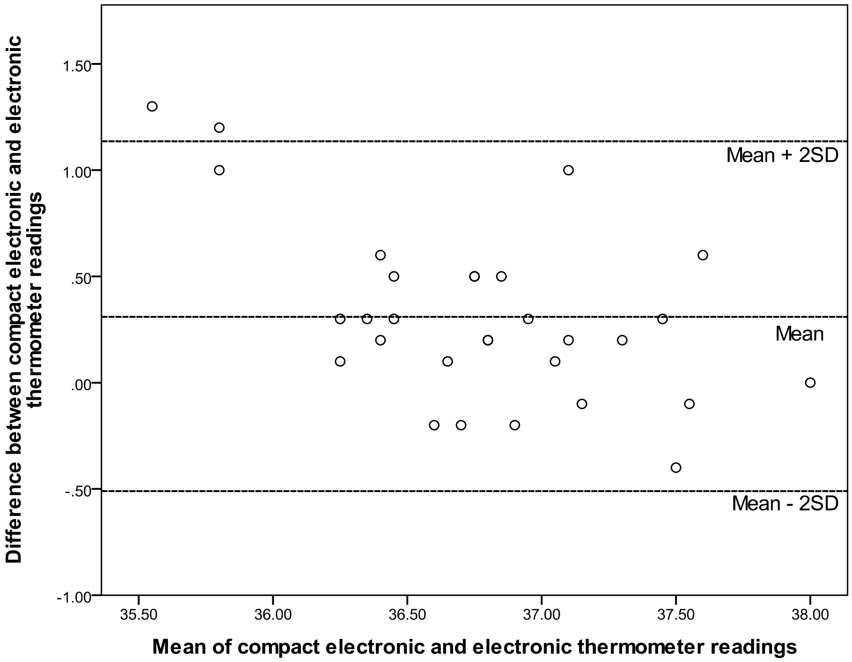


Figure 4: Bland-Altman plot of difference for the rectal site



Analysis among hospital departments was done to check for any change in results should the healthcare professional factor be controlled. Paired-sample t-test showed a statistically significant difference between the readings of the compact electronic and electronic thermometers for all hospital departments ($p < 0.001$). Correlation coefficients were all below 0.8 except for the neonatal intensive care unit (the unit where rectal measurements were taken). This echoes the previous findings and thus no further analysis was taken.

5.1.2.c Discussion

There is a paucity of studies comparing compact electronic to electronic thermometers. Sganga and colleagues (2000) compared compact electronic and electronic thermometers to a mercury thermometer and found a stronger correlation (R= 0.84) between compact electronic and mercury thermometers compared to electronic thermometer (R= 0.74) in an infant population using the axillary site. Correlation between compact electronic and electronic thermometer measurments was not reported. Mean difference between the readings of the compact electronic and electronic thermometers was 0.03°C in that study. Sganga and colleagues' (2000) study draws a better profile for the compact electronic thermometer when compared to the findings in this study. Still comparison between findings of different studies in this domain faces a lot of obstacles, including the inclusion of different populations and the utilization of different measurement sites and thermometer brands, thus limiting the generalizability and comparability of the findings. The methodological approach utilized in this study has never been before reported in the literature. Its importance stems from the fact that measurements were taken on a heterogeneous patient population and from different measurement sites, thus increasing the generalizability and comparability of the findings. Overall, findings in this study showed statistically and clinically significant differences in the readings of the compact electronic and electronic thermometers, even when controlling for the measurement site and the hospital department, thus the replacement of the more established electronic thermometer with the compact electronic thermometer is not recommended from an accuracy point of view.

5.2 Ease of use

Ten healthcare personnel including registered and practical nurses were recruited by the researcher to participate in this phase of the study. Recruitment was done through convenience sampling from the pool of nurses present on duty during that day. All in-patient departments were represented. Nurses were given a brief introduction about the utilization of the two thermometers and were given enough time to try the thermometers until they expressed confidence in their competence to use the thermometers. Measurements took place in the nurses' respective departments so that the usual setting of practice would not be altered.

5.2.1 Results

Time for measurement by electronic thermometer ranged between 19.28 seconds and 23.98 seconds across the three measurement attempts while the range for the compact electronic thermometer was between 32.11 seconds and 44.48 seconds. Number of steps for completing the measurement ranged between six to seven steps for both thermometers (Table 12).

Table 12: Duration and Number of Steps for Measuring Temperature with the Two Thermometers

	Thermometer type	N	Mean (SD)	Number of steps (range)
Measurement first time	Electronic	10	23.98 (3.51)	6 to 7
Electronic	Compact	10	44.48 (6.43)	6 to 7

Measurement second time Electronic	Electronic	10	19.28 (2.10)	6 to 7
	Compact	10	32.11 (7.26)	6 to 7
Measurement third time Electronic	Electronic	10	21.38 (4.79)	6 to 7
	Compact	10	32.57 (6.25)	6 to 7

Overall, it took on average 21.55 seconds to complete a measurement by electronic thermometer and 36.39 seconds to do it by a compact electronic thermometer, with a mean difference of 14.84 seconds (Table 13). Independent sample t-test (Table 14) showed that this difference is statistically significant ($p < 0.0001$). On the economic level, taking the average number of temperature measurements taken annually and the salary of the practical nurse in NGH into consideration, this mean difference in measurement duration would translate to a 1392 dollars in savings from personnel cost annually for NGH. The results presented indicate that the electronic thermometer is easier to use thus supporting its cost-effectiveness.

Table 13: Mean duration for measurement reading for all attempts (seconds)

Thermometer type	Mean (SD)	Mean difference
Electronic	21.55 (2.07)	14.84
Compact electronic	36.39 (4.45)	

Table 14: Independent samples t-test for mean duration for measurement

t-test for Equality of Means						
t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
					Lower	Upper
-9.546	18	.000	-14.842	1.55471	-18.108	-11.575

6 COMPONENT 3: EVALUATION OF THE TWO ALTERNATIVE THERMOMETERS FROM THE HEALTHCARE STAFF'S PERSPECTIVE

Five healthcare personnel (practical nurses) from five different hospital wards including adult medical/surgical unit, obstetrics and gynecology unit, adult intensive care unit, pediatrics unit, and neonatal intensive care unit were nominated by the nursing director in NGH to be part of this component of the study. Healthcare personnel utilized the compact electronic and electronic thermometer for five days on their respective wards to evaluate them regarding lifespan, accuracy, and ease of use. Evaluation was done using a multiple choice questionnaire (Appendix F) that included space for adding any comments that might help in evaluating the two thermometers.

6.1 Results

Healthcare staff's responses are summarized in table 15. The majority of staff (80%) thought that the electronic thermometer is more prone for breakage and thus could have a shorter life span. One practical nurse explained that because electronic thermometer is larger in size than compact electronic, it is more likely to be dropped and broken. Responses regarding accuracy of the thermometers favored slightly the electronic thermometer (40%). Another 40% of the staff thought that both thermometers gave comparable results and commented that they noticed a difference up to 1°C lower between the measurements of the electronic and compact electronic when compared to mercury thermometer and thus did not trust both thermometers. Regarding usability, electronic thermometer got most responses (80%) as the easier to use because of its bigger and clearer screen and easy to apply probe covers as cited by the healthcare staff.

Table 15: Healthcare staff’s opinions regarding durability, accuracy, and ease of use of the two thermometers

Question	Compact electronic	Electronic	Both are the same
Which thermometer is more likely to be broken during use?	-	80%	20%
Which thermometer do you think is more accurate?	20%	40%	40%
Which thermometer is easier to use?	20%	80%	-

Other comments centered about patients’ attitude and infection control issues. One healthcare staff from an adult ward reported that patients were pleased more with the electronic thermometer. However, infants were reported showing signs of discomfort when measurements were taken rectally using the electronic thermometer. Healthcare staff explained this as due to the thickness of the electronic thermometer probe. Infection control was an issue for the compact electronic thermometer according to the staff. An adult medical/surgical staff reported that the equipments used for patients on isolation are kept in their rooms, which might increase the possibility of losing the compact electronic thermometer because of its small size. More importantly, the nylon probe cover of the compact electronic thermometer was thought to be not of enough protection from contamination since micro-tears may happen to the probe cover during measurement, thus affecting its integrity. Moreover, manual removal of the probe cover of the compact electronic thermometer may pose a risk of contamination of the healthcare staff’s hands or gloves.

6.2 Discussion

Life span and durability is poorly reported in the literature. According to these findings, the compact electronic thermometers were thought to be more resilient. Healthcare staff's trust in the performance of the both thermometers was an issue. Comparison between the readings of the standard mercury thermometer and the two alternative thermometers, although not intended by the study was inevitable; moreover, it created doubt in the performance of the two thermometers. Although there are many valid reasons for such a discrepancy, comparison between the performance of the two alternative thermometers and the used mercury thermometers was not among the goals of this study. The implications of this will be discussed in the conclusion of this study.

The results about the ease of use echo the previous findings, thus supporting the conclusion about the user-friendliness of the electronic thermometer. Patient acceptability of the thermometer favored the electronic thermometer for adults and the compact electronic thermometer for the infants when using the rectal site. Greenes & Fleisher (2001) compared infant experience with temperature measurement using the electronic thermometer rectally versus a tympanic membrane and temporal artery infrared thermometers and reported high discomfort level with rectal measurement. This deserves further investigation with regard to the use of the rectal route and not axilla as preferred route for neaonates. The healthcare staff's comments showed a clear advantage for the electronic thermometer over the compact electronic regarding infection control measures. Overall, electronic thermometers were reported to be easier to use, patient friendly, and better for infection control purposes, compact electronic thermometers were reported to be more durable, while trust in the performance of both thermometers was a challenge, less for the electronic thermometer than the compact electronic thermometer.

7 CONCLUSION

7.1 Conclusion

Mercury thermometers as the second largest reservoir of mercury after sphygmomanometers should be eliminated from the healthcare system for the sake of the patients, healthcare personnel, and the environment. Determining what is the best alternative to mercury thermometer among the available technologies depends on many factors that are market and healthcare facility specific. The non-mercury thermometer should first and foremost be accurate and reliable. It should also be eco-friendly, durable, easy to use, of low maintenance and pleasant for the patients. Last but not least, it should be cost effective.

The available literature supports the superiority of the electronic thermometer above its counterparts as a reliable, accurate, and safe alternative to mercury thermometers. The approach used in this study utilized multiple sources of information to determine the best alternative for mercury thermometer for the Lebanese healthcare sector. Market survey of medical equipment vendors showed availability of several technologies of thermometry. Economic comparison of the different alternatives showed the cost effectiveness of the electronic thermometer, especially on the long run. Nursing leadership favored two alternative thermometers for further evaluation, the electronic and the compact electronic. Clinical evaluation of the two alternative thermometers showed that their readings differed significantly, both statistically and clinically. Since the electronic thermometer is the more established alternative as per the literature, the compact electronic thermometer was not found to be an accurate replacement for it. Clinical evaluation of the ease of use reflected a significant difference in the measurement time, again favoring the electronic thermometer. The nursing staff expressed preference for the electronic thermometer regarding its user friendliness, patient acceptability, and infection control, while compact electronic thermometer was favored for durability. Taking these findings collectively, this study provides evidence for the superiority of electronic thermometer of the brand available in the Lebanese market as the best alternative for mercury thermometer.

7.2 Limitations

The strength of this study being the first to be done in Lebanon stems from the different sources of information used for evaluation, an approach that has not been reported in literature before. However, there were some limitations that should be addressed in later studies. First the study was done in a rural governmental hospital that may differ from other Lebanese healthcare institutions in various ways, especially when it comes to nursing leadership and staff preferences regarding the alternative thermometer. This highlights the need to repeat the study in several healthcare institutions with different characteristics reflective of the diversity present in the Lebanese healthcare sector. Second the clinical evaluation of the thermometers regarding accuracy lacked a standard reference thermometer for comparison, thereby limiting the validity of the comparison. This is critical when it comes to identifying febrile patients. The two alternative thermometers' readings lacked agreement more than half of the time for febrile patients without the possibility of identifying sensitivity or specificity of the readings. Moreover, doubt in the accuracy of both thermometers was a noticed finding in the nursing staff preference questionnaire. This highlights the need to utilize a reference thermometer in future studies, especially in view of the paucity of literature comparing the two thermometers considered in this study.

Finally, this study should set the stage for a national guideline for mercury thermometer phase out from the Lebanese healthcare sector in hope of issuing an official decree banning the utilization of mercury containing healthcare equipments. Until then, the author expects this study to be of guidance for hospitals intending to phase out their mercury thermometers.

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Appendix A

Protocol for taking patients' temperature

1- Nurse Manager identifies candidates from the pool of patients admitted to the unit.
2- Nurse Manager approaches each candidate to obtain a written consent.
3- In case of a pediatric patient, a parent's written permission in addition to the child's assent will be obtained by the Nurse Manager.
4- The consent will be obtained in a place that preserves patient's confidentiality as per the Nurse Manager's discretion.
5- Nurse Manager will be guided by the printed consent in explaining the study, risks, and benefits.
6- The Nurse Manager will verify with the patient's nurse the appropriate site of temperature measurement.
7- Nurse Manager will inform the practical nurse about the name of the participant, room number, and selected site of temperature measurement.
8- The practical nurse will take the temperature using the two thermometers as per the guiding manual and record on the prepared form.
9- The practical nurse will also record the age and sex of the participant.
10- To decrease the *drawdown* phenomenon[9] (Giuliano et. al., 2000), temperature measurement will be taken in the following manner:

    a- For oral site, each reading will be taken from the opposite pocket under the tongue.
    b- For axillary site, each reading will be taken from the opposite armpit.
    c- For rectal site, readings will be separated by a one minute interval.

11- To decrease the risk of nosocomial infections, thermometers will be used with probe covers and wiped by a disinfectant (isopropyl alcohol 70%) after each use. Moreover, different compact electronic (i.e. digital) thermometers will be used for rectal and oral/axillary sites. Labels specifying the intended site/s of measurement will be placed on the case of each thermometer.
12- To fairly distribute the burden of the study, temperature measurements will be taken from different patients as much as possible. In case of insufficient patient population, measurements may be repeated on the same patient not to exceed two sets of measurements per nursing work shift (i.e. 8-12 hours).

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[9] It is the conductive heat loss effect that occurs when two objects come into contact and heat passes from the warmer to the cooler object.

Appendix B

Table 16: The specifications of different types and brands of thermometers

Brand	Type	Measuring range	Ambient temperature operating range	Response time (in seconds)	Warning T. when out of range	start-up self-check	peak temperature alarm	Memory function	Automatic shut-off	battery life	Customized colors for different sites	Others	Maintenance	Battery type	Standard met
Flex Temp smart MC-343F-E (Omron)	Digital			10 (20s oral, 10s rectal, 25s underarm)			Yes	Yes	Yes		No	flexible tip, waterproof, eco friendly			EN 124700-2000
Eco Temp Smart MC-341-E (Omron)	Digital	32.0 to 42.0°C	10 - 40°C, Relative Humidity 30 – 85%	20s oral, 10s rectal, 25s underarm	No	Yes	Yes	Yes	Yes (30 min. after use or 3 min. when turned on but not used)	Approx. 2 years or more (3 times per day)	No	waterproof, Guaranteed for 3 years	check manual	1.5V DC Alkaline-Manganese Button LR41	EN 124700-2001
GIMA 25560	Digital	32°C-42°C		60	No	No	Yes	Yes	Yes	100 hours of uninterrupted use	Yes	Automatic calculation of core temperature when taken from different sites (vendor claims)	Not specified	Not specified	CE 0476/ FDA
GT004-230 (Greet med-China)	Digital	32°C-43°C	10-35°C	Oral: 60s Axillary: 100s Rectal: 60s	No	No	Yes	No	No	About 100 hours under continuous operation	Yes	flexible tip	Not specified	1.5V button battery (LR/SR-41)	Not specified
GT004-204 (Greet med-China)	Digital	32°C-42°C	Not specified	Not specified	No	No	Yes	No	No	4000-5000 times	Yes		Not specified	AG3 1.5V	Not specified

Brand	Type	Measuring range	Ambient temperature operating range	Response time (in seconds)	Warning T. when out of range	start-up self-check	peak temperature alarm	Memory function	Automatic shut-off	battery life	Customized colors for different sites	Others	Maintenance	Battery type	Standard met
DT-11	Digital	32°C-42°C	5 - 35°C, ≤80%RH	Rectal: 40-60 Axillary:80-120 Oral:50-70	No	Yes	Yes	No	No	minimum 100 hours under continuous operation	No	Warranty: 1 year	Not specified	1.5V DC Alkaline-Manganese Button LR41	EN 12470-3, waterbath accuracy data available
SpeedRead V911 (Vicks)	Digital	89.6 - 109.2°F	Not specified	10-12s	Yes	Yes	Yes	Yes	Yes (1.5 min)	300+ measurements	No	Warranty: life time	Not specified	3V, CR1225 silver oxide type	waterbath accuracy data available
ComfortFlex V965F (Vicks)	Digital	89.6 - 109.2°F	Not specified	10-12s	Yes	Yes	Yes	Yes	Yes (1.5 min)	300+ measurements	No	Warranty: life time Flexible tip	Not specified	3V, CR1225 silver oxide type	waterbath accuracy data available
MT16 F1 (Microlife)	Digital	32.0°C - 43.9°C	10 °C - 40 °C	60	No	Yes	Yes	Yes	Yes (9 mins)	N/S	No	Guaranteed for 5 years	verify the accuracy by an authorised laboratory **every 2 years**	1.5 / 1.55 V; LR 41	EN 12470-3, ASTM E1112, IEC 60601-1, IEC 60601-1-2 (EMC)
MT 200 (Microlife)	Digital	32.0 °C - 43.9 °C	10 °C - 40 °C	10	Yes	Yes	Yes	Yes	Yes (10mins)	N/S	No	flexible tip, waterproof, Guaranteed for 5 years	test for accuracy **every 2 years** or after mechanical impact (e.g. being	1.5/1.55 V; SR 41	

Brand	Type	Measuring range	Ambient temperature operating range	Response time (in seconds)	Warning T. when out of range	start-up self-check	peak temperature alarm	Memory function	Automatic shut-off	battery life	Customized colors for different sites	Others	Maintenance	Battery type	Standard met
													dropped)		
Suretemp Plus 690	Electronic	26.7°C-43.3°C	10 °C - 40 °C	Oral (4-6) Adult Axillary (12-15) Pediatric Axillary (10-13) Rectal(10-13)	No	Yes	N/A	Yes	Yes	Approx. 6000 temperatures	Yes		preventive maintenance performed **every six months**	Three 1.5Vdc AA alkaline batteries	Not specified
NC100 (Microlife)	Temporal	34.0-42.2 °C	16-40.0 °C	3	Yes	Yes (display malfunction signs)	Yes	Yes	Yes (1 min)	Not specified	N/A	Multiple use, Guaranteed for 2 years	**biennial** technical inspection is recommended	2 x 1.5 V Batteries; size AAA	ASTM E1965; IEC 60601-1; IEC 60601-1-2 (EMC)
TAT-5000 (Exergen)	Temporal	15.5-42.0°C	16-43°C	0.04	No	Yes (display malfunction signs)	Yes	No	Yes (30 sec)	Approx. 15,000 readings	N/A	Silver-ion anti-microbial probe head destroys harmful bacteria and fungi on contact	**not routine** only when needed	9V Alkaline battery	ASTM E1112

Brand	Type	Measuring range	Ambient temperature operating range	Response time (in seconds)	Warning T. when out of range	start-up self-check	peak temperature alarm	Memory function	Automatic shut-off	battery life	Customized colors for different sites	Others	Maintenance	Battery type	Standard met
V977US (Vicks)	Temporal	Not specified	60.8° and 104°F	3 seconds	Yes	Not specified	Yes	Yes		1000 to 1500 measurements	N/A	3 year warranty	Not specified	Not specified	Not specified
PRO 4000 (Welch Allyn – Germany)	Tempanic	20-42.2 °C	10-40 °C	3-7 seconds	No	Yes	Yes	Yes	Yes (1 min.)	6 months/ 1000 measurements	N/A	Shock: withstands drop of 3 feet Can be used with a rechargeable battery pack	It is recommended Operational Verification performed **annually**	two 1.5 V batteries type AA (LR 6)	ASTM Standard E 1965-98
ThermoScan IRT 3020 (Braun)	Tempanic	34 - 42.4 °C	10 °C to 40 °C	1 second	No	Yes	Yes	Yes	Yes (1 min.)	1000 measurements	N/A	2 years warranty probe tip ejector	Not specified	two 3 V lithium batteries (CR 2032/DL 2032)	ASTM Standard E 1965-98
ThermoScan IRT 4520 (Braun)	Tempanic	35 - 42.4 °C	10 °C to 40 °C	Not specified	No	Yes	Yes	Yes	Yes (1 min.)	1000 measurements	N/A	3 years warranty	Not specified	two 1.5 V type AA (LR 06)	ASTM Standard E 1965-99
GentleTemp MC-510-E2 (Omron)	Tempanic	34°C - 42.2°C	10 - 40°C Relative humidity : 30 - 85%	Not specified	No	Yes	Yes	No	No	approx. 5000 measurements	N/A		For professional use it is recommended to check once a year.	3V DC (lithium battery CR2032)	According to NEN-EN 12470- 5 Clinical thermometers – Part 5 Performance of infra-red ear thermom

Brand	Type	Measuring range	Ambient temperature operating range	Response time (in seconds)	Warning T. when out of range	start-up self-check	peak temperature alarm	Memory function	Automatic shut-off	battery life	Customized colors for different sites	Others	Maintenance	Battery type	Standard met
															eters 34°C – 42.2°C: ±0.2°C
GT004-250 (Greetmed-China)	Tempanic	34°C - 44°C	16 - 35°C Relative humidity : 80%	Not specified	No	Yes	Yes	Yes		4000 takes	N/A		Calibration frequency: two years	two 1.5V alkalescence batteries (AAA)	Not specified 0.2°C (from 35.5°C to 42.0°C)

Appendix C

Important Attributes for the Non-mercury Thermometers

The following questions are formulated to explore your opinions regarding the important features that should be present in the non-mercury thermometer to be used.

1- How important is it for the thermometer to produce a warning when temperature is out of range (i.e. $T \leq 36°C$ or $T \geq 38°C$)?

a. Very important b. Somewhat important c. Not important

2- How important is it for the thermometer to have a memory function that stores previous temperature readings?

a. Very important b. Somewhat important c. Not important

3- How important is it for the thermometer to have standard disposable sterile probe covers instead of regular disinfection of probe tip?

a. Very important b. Somewhat important c. Not important

4- How important is it for the thermometer to have a digital display of result instead of any other indicator (i.e. chemical or visual)?

a. Very important b. Somewhat important c. Not important

5- How important is it for the thermometer to have customized colors to distinguish between oral, rectal, and axillary use?

a. Very important b. Somewhat important c. Not important

6- How important is it for the thermometer to have a flexible probe tip?

a. Very important b. Somewhat important c. Not important

7- How important is it for the thermometer to have an audible alarm when the peak temperature is reached?

a. Very important b. Somewhat important c. Not important

Please add any feature that you think is important for the non-mercury thermometer to have:

____

____

Appendix D

Table 17: Types of costs and their calculation methods

	Type of cost	Calculation Method
Investment Costs	Total cost of thermometers	Unit cost x estimated quantity needed annually
	Total cost of accessories	Unit cost x estimated quantity needed annually
	Cost of calibration equipment	Cost of calibration equipment
Running Costs	Batteries	unit cost x (annual number of temperature measurements /useful life[10])
	Probe covers	unit cost x annual number of temperature measurements
	Alcohol Swabs	Unit cost x annual number of temperature measurements
	Calibration cost	medical engineer time x salary x annual calibration frequency
	Personnel cost (direct)	measurement time x annual number of temperature measurements x nursing salary per min/sec
	Maintenance cost	5% of the purchase cost
	Replacement cost	Percentage of thermometers replaced annually

Table 18: Data collected from NGH

Practical Nurse’s salary (USD/Minute)	0.0375
Biomedical engineer’s salary (USD/Minute)	0.0472
Total number of inpatients (2009 – 2010)	9,186
Average number of outpatients per day	133

Appendix D

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[10] Useful life indicates the number of measurements that a battery can sustain.

Table 19: Measurement and calibration time for the different compact electronic thermometers

Type of thermometer	Flex Temp smart MC-343F-E (Omron)	Eco Temp Smart MC-341-E (Omron)	GIMA 25560	DT-11	SpeedRead V911 (Vicks)	ComfortFlex V965F (Vicks)	MT16 F1 (Microlife)	MT 200 (Microlife)	GT004-230 (Greet med-China)	GT004-204 (Greet med-China)
Measuring Time (s)	18	18	60	80	11	11	60	10	80	39
Calibration time (min)	17.25	17.25	57.5	76.67	10.54	10.54	57.5	9.58	76.67	37.38

Appendix E

Calculation of calibration time

Compact electronic

Water bath method: "*Tests should be conducted at two or more points within the practical temperature range of the device, such as at 36, 38, 40 and 42 ºC. Conduct the tests three times to determine repeatability.*" (BS EN 12470-4, 2000)

It is assumed that it takes about 20 minutes to heat the bath up to the first temperature set point, then 6 minutes to raise the temperature of the bath to the next set points and allow it to stabilize, plus the average measuring time of 39 seconds, times 4 temperature set points, that gives 2,436 seconds (40.6 minutes). Doing this test a second time as the bath cools down takes longer to stabilize. It is assumed that 12 min are needed to stabilize per temperature set point, plus the 39 seconds measurement time for three set points (i.e., not including the highest set point) gives another 2,277 seconds (37.95 minutes). Then repeating a third time by heating the bath up for another three set points gives 1,197 seconds (19.95 minutes). All three tests add up to 5,190 seconds (98.5 minutes). If the technician did four thermometers at the same time, this gives 1,477.5 seconds per thermometer or 24.6 minutes per thermometer.

Electronic

For the Welch Allyn, it is assumed that Model 9600 Plus Calibration Tester is used. The calibration time is estimated as follows: 6 minutes for stabilization to the first set point, 6 minutes for cleaning and drying, 1 minute for measurement, then 6 minutes stabilization + 1 minute for the next two set points. Total calibration time is 27 minute per electronic thermometer.

Infrared tympanic & Infrared temporal

Three set points will be taken. For the first set point the estimated calibration time is as follows: cleaning and drying probe-6 minutes, calibration mode set up-about 10 seconds, stabilize probe-3 seconds, measurement-about 3 seconds. Second measurement at first set-point: wait-1 minute, stabilize-3 seconds, measure-about 3 seconds. Same for third measurement. The total for the first set point: 508 seconds (8.5 minutes). For the second set point: assume 6 minutes to reach new set point and stabilize; calibration mode-10 seconds, probe-3 seconds, measurement-3 seconds; repeat for 2nd and 3rd measurement. Total for second set point: 508 seconds (8.5 minutes). Total calibration time for all three set points = 1524 seconds (25.4 minutes) per thermometer.

Appendix F

Evaluation of the two alternative thermometers from the healthcare staff's perspective

Please answer the following questions:

1. Which thermometer is more likely to be broken during use?

   [ ] thermometer 1 [ ] thermometer 2 [ ] both are the same

2. Which thermometer do you think is more accurate?

   [ ] thermometer 1 [ ] thermometer 2 [ ] both are the same

3. Which thermometer is easier to use?

   [ ] thermometer 1 [ ] thermometer 2 [ ] both are the same

Please add your comments below