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Design and Implementation of Thermostat (Digital and Mercury)

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Annotation: Digital thermometers :- Digital thermometers work by using heat sensors that determine body temperature and display reading numerically on the digital screen.Digital thermometers can be used to take temperature readings in the mouth, rectum, or armpit.Oral temperature can be measured by either a digital or mercury thermometer

Mercury thermometers: - Mercury thermometers are mercury-in-glass thermometers. Do not use mercury thermometers; they can break, releasing small fragments of glass and highly poisonous mercury.

Working Principle of the Device: - Digital thermometer is a less hazardous instrument use for taking/recording temperature from a specific body. It works just like a liquid in glass thermometer but in a different way

because of its accuracy in reading, the temperature of the given body is taken by the temperature sensor (LM35) and feed into the microcontroller (PIC16F877A) where the conversion takes place. The ADC port of the microcontroller(PIC16F877A) is interfaced with the temperature sensor which allows it to have direct access to the temperature reading from the sensor, the reading taken from the temperature sensor is been processed by the microcontroller to be given as an output on the LCD display screen. The LCD displays the processed data given to it by the microcontroller while the potentiometer is used as contrast level changer for the LCD (increase and decrease level of brightness for the LCD screen). The oscillatory circuit works at 8 MHz rate and it serves as clock counter for the microcontroller allowing the microcontroller to mead between logic 1 and 0 synchronously.

Mercury thermometer work on the principle :- of thermal expansion of liquids. In case of mercury thermometer, mercury (liquid) expands when the temperature increases. This rise in the level of mercury gives the temperature readings.

Children's decisions concerning investigation and treatment may be based on the results of temperature alone. Although the accuracy of axillary temperature measurement is affected by a number of factors, device dwell time and device type are common. Objective. Compare body temperature between glass mercury thermometer (GMT) and digital thermometer (DT). Method. Comparative descriptive study was used. A total of 101 samples were taken with convenient sampling technique, but 98 were analyzed. Statistical significance ($p < 0.01$) and clinical significance (MD $\geq$ 0.2∘C) were used in the analyses. Correlations and Bland-Altman plots were used to observe agreements of the recording. Results. Mean difference (MD) of 10 min GMT and DT was 0.13 $\pm$ 0.11. Statistically significant differences were noted in 10 min GMT and DT

(p < 0.00). But the correlations were strong positive (r > 0.75) and all MD were at the limit of agreement in Bland-Altman plot. Clinically, it is not significant (MD < 0.2∘C).

Conclusion and Recommendations. Even though statistical significant differences (p < 0.001) were noted between 10 min GMT and DT, the strong correlation, good agreements, and clinical insignificances make DT good alternative to the traditional GMT. Their variation in temperature is not likely to change any clinical decision. So, health professionals should use DT for measuring body temperature in under-5 febrile illnesses

Keywords: Digital thermometer, Mercury thermometer, Temperature sensor, Microcontroller, LM35, PIC16F877A, Body temperature measurement, Clinical accuracy, Axillary temperature, Thermometer calibration, Health technology, Thermometry, Fever detection, Pediatric care, Medical devices, Nursing practice.

Introduction

Background and Statement of the Problem. Body tem- perature is2m easure of the body's ability to generate and get rid of heat. The normal physiology is to keep body temperature within a narrow safe range in spite of large variations in environmental temperatures [1]. Maintenance of body temperature occurs through the integration of multiple body systems that interact to maintain a balance between heat loss and generation. Normal body temperature is around 37∘ C (98.6∘ F) but varies during the day. The lowest body tem- perature occurs in early morning hours (2 am to 4 am) and the highest temperature occurs in the late afternoon. Body temperature may also increase as a result of overdressing or strenuous exercise, especially in hot weather [2]. Febrile illness is defined as a disease characterized by an increase of body temperature more than 37.5∘ Cresulting from infectious process. Febrile illnesses (FIs) due to different eti- ologic agents are the most common causes of morbidity and mortality in developing tropical and subtropical countries [3]. Many of the infectious diseases assessed, classified, and treated using the Integrated Management of Childhood IIlnesses (IMCI) guidelines have fever as a secondary cause. For example, many children with upper respiratory tract infection, pneumonia, or ear infection will have fever. Severe illnesses associated with danger signs are also associated with fever, such as sepsis septicemia and meningitis. The danger signs lead to appropriate referral for the illness. Fever is also associated with malaria, dysentery, and diarrhea in children. In these patients, the cause of the fever is treated and fever is not used in decision making. While these conditions all cause fever, the management of the condition itself results in the management of the feverCause A thermometer is a device that measures temperature or temperature gradient, using a variety of principles. For recording body temperature, several different types of thermometers are used, such as mercury thermometers,

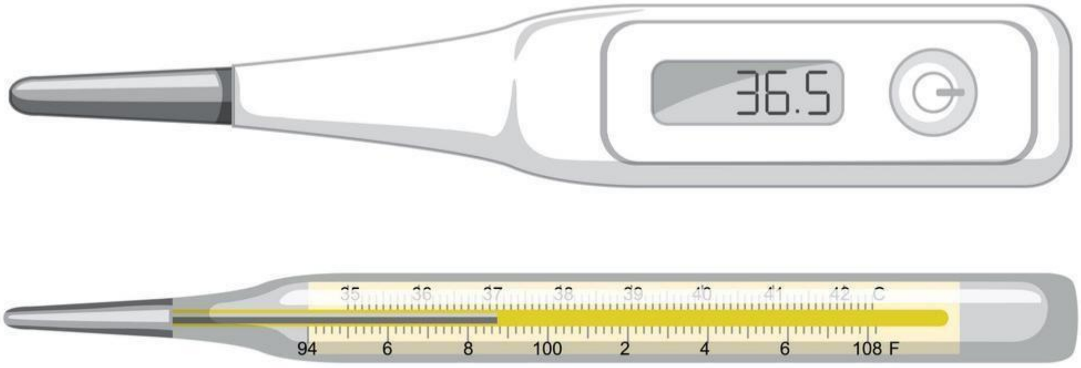


Figure 1: Digital and glass mercury thermometer

digital thermometer, liquid crystal forehead thermometer, and infrared tympanic thermometer [1]. Observe glass mercury and digital thermometers in Figure 1. Body temperature in children can be measured at a number of anatomical sites using a range of different types of thermometers, including mouth, rectum, and axilla [5]. Ideally, measurement should be reliable, noninvasive, non- traumatic, culturally acceptable, user friendly, and hygienic. Since rectal temperature measurements are relatively more time-consuming, invasive, uncomfortable, less hygienic, and unacceptable in many cultures, and oral temperature is unhygienic and difficult in children, axillaries measurements have been the method of choice in many countries [6– 8]. Evaluation of body temperature is one of the oldest known diagnostic methods and is still an important sign of health and disease, both in everyday life and in medical care. The individual can describe feelings of illness and discomfort, but in conditions where individuals are unable to explain themselves, for example, children, the nurse has to interpret the clinical signs and rely on objective measurements [9]. Change in body temperature is one of the most important physical sign and symptom in both acute febrile illness and chronic illnesses in children. This is especially important in newborns, in which fever can be indicative of infection. It was shown that temperature out of the normal range is closely related to the survival of infants [6, 7, 10, 11].

Many decisions concerning the investigation and treatment of children may be based on the results of temperature measurement alone [12, 13]. As the basic sciences develop, temperature measurement methods and devices were improved. For hundreds of years, both in clinics and in home, GMT was the standard of human temperature measurements [14] and currently developing countries are using it commonly [15] though it is no longer recommended [11, 13, 16–19]. DTs are widely used by health- care professionals as an alternative to GMT as they are faster and easier to read and avoid the environmental concerns of mercury [5, 19]. Although accuracy of axillary temperature measurement is affected by a number of factors, including ambient tem- perature, local blood flows, inappropriate placing of the probe, closure of the axillary cavity, and device dwell time, device type is common which can led to false high readings which may lead to expensive and painful diagnostic studies and medical interventions or false low readings which may lead to greater morbidity and mortality. So, temperature measurement must be accurate and consistent, as decisions about therapeutic intervention are based on it [9, 20–24]. The accuracy of devices to record and grade temperature is uncertain [1]. Limited researches have addressed whether the thermometer correctly identifies patients with hyper- thermia or hypothermia. In general, these studies indicate that noninvasive temperature measurements are accurate in ruling out hyperthermia and hypothermia, but they may fail to detect hyperthermia and hypothermia, depending on the thermometer used. In particular, there is controversy in alternative approach of digital to mercury thermometers regarding accuracy and sensitivity [25]. So, this study may address the gap among health professionals.

1.2. Rationale and Significance of the Study. Temperature taking is the most frequently performed clinical observation and is predominantly a nursing task. Although the use of digital thermometer is gradually increasing, GMT is still the most common device used in the pediatric setting, especially in developing countries [15] in spite of having long dwelling time, danger of breakage, potential harm and toxic vapor.

effects; difficulties in reading, and possible role in spread of hospital acquired infections [11, 13, 16–19, 26]. Current nursing studies on temperature measurement are conducted to understand the efficacy of the various types of equipment available to measure temperature [27– 29], but they are insufficient and contradictory [30]. In particular, there is debate between GMT and DT regarding their accuracy in measuring true body temperature and their ability to detect fever and hypothermia. Researches on those devices are scarce besides the manufacturer's data sheets. Even the little documented studies have large discrepancy and health professionals are in debate. Due to inconsistencies in both research methods and clinical practice [31, 32], nurses are challenging in selecting the measurement method that is most appropriate for a patient and provides the most accurate and precise approximation of core temperature [33]. The false low and false high result related to accuracy of thermometer device and dwelling time may lead to misdiag- nosis and treatment. If DTs are to become the standard device used in the clinical setting, they must be subjected to rigorous investigations to increase the knowledge of practitioner and thereby improve practice. Febrile illnesses are the most common leading cause of morbidity and mortality in under-5 children which needs accurate measurement of body temperature. Ethiopia is one of the developing countries which use both GMT and DT in measuring body temperature with the uncertainty of the device and dwelling time in their capability of detecting hyperthermia and hypothermia. So, it is important to know the standard time and accurate device to measure body temperature.

Methods

This study fills the gaps among health professionals and has some input on nursing body of knowledge. It will have contribution for decision makers and significant others to take possible measure on temperature measurement device. It may decrease misdiagnosis of febrile illness in under-5 children related to inaccuracy of body temperature measurement due to devices type. This study will also be used as a base line data for further research on comparison of temperature measuring devices related topics. It is designed to investigate whether DT is suitable alternative to GMT in children.

Research Question. Can digital thermometer be used as alternative device with old standard GMT in axillary site in under-5 children with febrile illness?

Literature Review

2.1. History of the Thermometer.

The temperature of the human body has been used as a diagnostic sign since the earliest days of clinical medicine. The earliest thermal instruments were developed during the sixteenth and seventeenth centuries. In 1665, it was suggested that the melting point of ice and the boiling point of water should be the standard. The most common scales today are the Fahrenheit, Centigrade, and the Kelvin scales. Since the earliest days of medicine, physicians have recognized that the human body can exhibit an abnormal rise in temperature, usually defined as fever, as an obvious symptom of illnesses. In 1868, Wunderlich established that the temperature in a healthy person is constant and that variation of temperature occurs in disease. The Allbutt thermometer was the first practical device to become commercially available. The technology has then improved to provide highly accurate devices, for example, thermal imaging; its use is still growing in medicine. The temperature of the human body has been used as a diagnostic sign since the earliest days of clinical medicine. Hippocrates taught that the human hand can be used to judge the presence of fever as early as 400 BC, but instruments to measure this temperature were not developed until the sixteenth and seventeenth centuries. Even then, the journey to the routine measurement of temperature in clinical practice was a long one, with many different people contributing to the arrival of the small, inexpensive, and accurate instrument known throughout the world as 'the clinical thermometer'. A thermometer is essentially an instrument that can measure temperature. It detects changes in physical properties of an object or substance as the temperature of the object changes. The expansion and contraction of air with changes in temperature was noted as early as 220 BC by Philo of Byzantium. It was later realized that water also has this property, as do other fluids and metals such as mercury. As a result, there are now many different forms of thermometers which have been developed over a period of several hundred years.

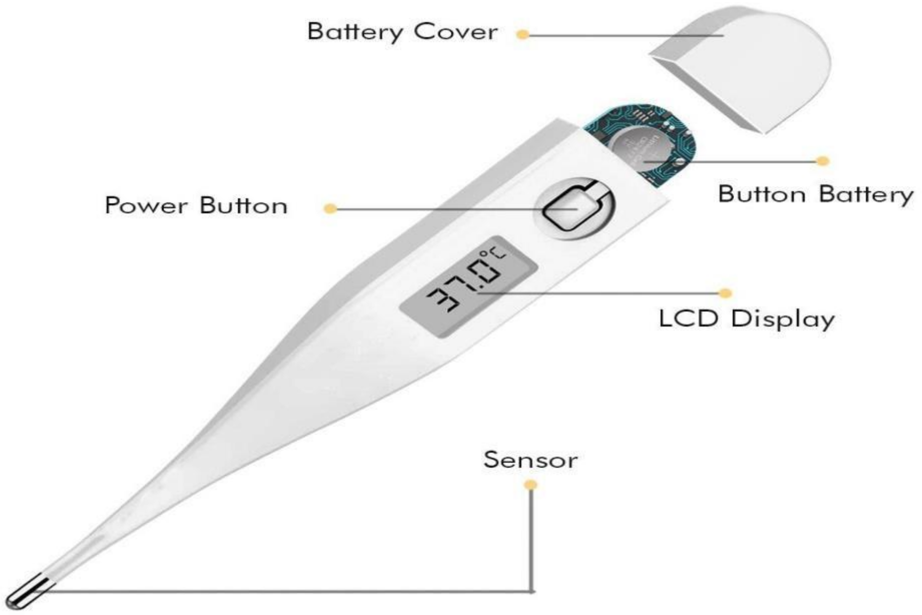
2.2. Digital thermometers.

Digital thermometers work by using heat sensors that determine body temperature and display reading numerically on the digital screen. Digital thermometers can be used to take temperature readings in the mouth, rectum, or armpit.Oral temperature can be measured by either a digital or mercury thermometer.

2.2. Mercury thermometers.

Mercury thermometers are mercury-in-glass thermometers. Do not use mercury thermometers; they can break, releasing small fragments of glass and highly poisonous mercury.

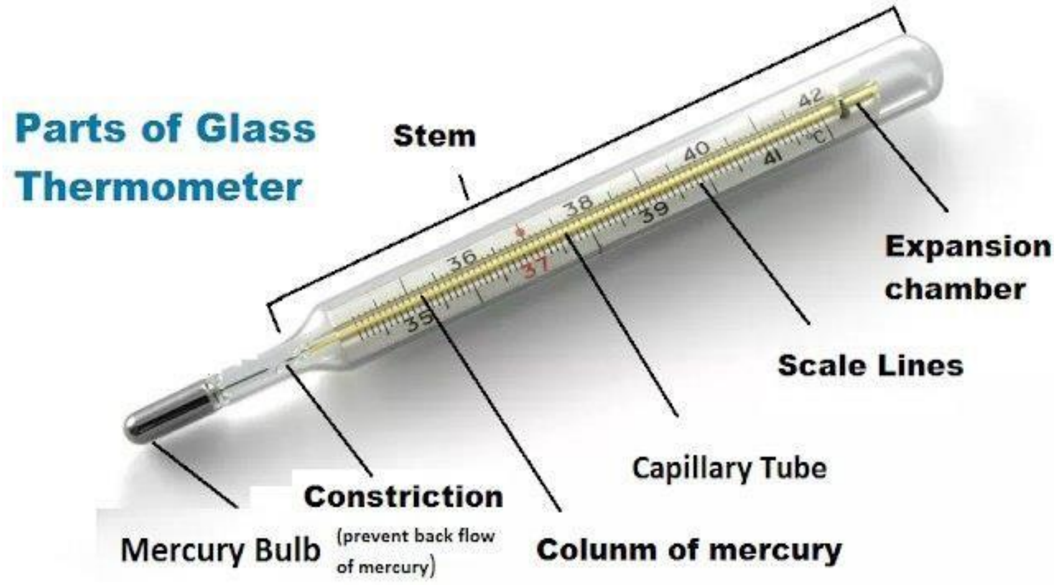
2.3. Components of the Digital and Mercury Thermometer.



- Components Digital Thermometer:-
- ✓ This device can measure temperature orally, rectally, and underarm.
- ✓ It has a 3-digit display in Celsius or Fahrenheit with 0.1-degree increments and beeps when measurement is complete.
- The accuracy of measurement is ±0.1 degree Celsius in the range of 32.0 to

42.0-degree Celsius.

- ✓ The device has an auto-off function that turns off approximately 30 minutes after use or 3 minutes when not in use.
- ✓ The device is waterproof



- Components Mercury Thermometer :-

1. Stem.

The stem is a longer part of the glass thermometer.

2. Mercury Bulb.

The bulb of the clinical thermometer is spherical in shape to store the mercury and is usually made of stainless steel. The bulb is the lowest part of the glass thermometer, which acts as a reservoir to hold mercury. It contains a small amount of mercury. Mercury is a metal, at the ordinary temperature, it is in liquid form. Mercury expands in response to heat. If the temperature is high then mercury in the bulb moves up the capillary tube. Mercury leaves the bulb, when the temperature rises and when the temperature descends, the mercury returns to deposit inside the bulb.

3. Capillary tube.

The capillary or stem is the tube of the mercury thermometer through which the mercury flows. The capillary tube is present inside the glass thermometer, and it is connected to the bulb. The capillary tube is the long cylindrical tube in a mercury thermometer that is connected to the bulb. When the temperature rises up, the mercury flows up the capillary. Where capillary tube ends, after that section known as the expansion chamber.

4. Expansion chamber.

The expansion chamber of the mercury thermometer is found at the top of the capillary. The expansion chamber function is to form a larger volume. If the maximum temperature scale is exceeded, then through which the mercury can fill.

5. Scale lines.

Scale line in thermometer is divisions of equal length (degrees) marked on the thermometer that indicate the units of measurement. It depends on the type of thermometer that can have ° F or ° C. When the temperature increases, the mercury inside the bulb rises and when cool, it goes down. Scale line shows how far the mercury rises and goes down, marks on the body of the thermometer indicate the temperature level.Know here normal body temperature range.

6. Constriction.

Constriction in the thermometer prevents mercury from backflow into the bulb when the reading is being taken.The constriction part is narrower than the stem; it causes the mercury to slow down and gives the user the necessary time to read the temperature reached.

2.4. Advantage and disadvantage in Digital and Mercury Thermometer.

- The following are the advantages and disadvantages of the digital Thermometer.

Advantage	Disadvantage
Quick and accurate reading.	Can be expensive.
Easy to use.	Needs batteries to operate.
Safe and hygienic.	Accuracy Can vary.
Portable and Compact.	Can break easily.
Stores previous temperature.	Not always user friendly.

- The following are the Advantages and disadvantages of the Mercury Thermometer.

Advantage	Disadvantage
Cheap.	Display is harder to read.
Durable.	Does not work below -39 C (Hg freezing pount).
Accurate.	Can't be uesd for thermograph.

2.5. Working Principle of the Device Digital and Mercury thermometer .

- Work Principle Digital Thermometer:-

Working Principle of the Device Digital thermometer is a less hazardous instrument use for taking/recording temperature from a specific body. It works just like a liquid in glass thermometer but in a different way because of its accuracy in reading, the temperature of the given body is taken by the temperature sensor (LM35) and feed into the microcontroller (PIC16F877A) where the conversion takes place.

The ADC port of the microcontroller(PIC16F877A) is interfaced with the temperature sensor which allows it to have direct access to the temperature reading from the sensor, the reading taken from the temperature sensor is been processed by the microcontroller to be given as an output on the LCD display screen. The LCD displays the processed data given to it by the microcontroller while the potentiometer is used as contrast level changer for the LCD (increase and decrease level of brightness for the LCD screen). The oscillatory circuit works at 8 MHz rate and it serves as clock counter for the microcontroller allowing the microcontroller to read between logic 1 and 0 synchronously.

- Work principal of the Digital Thermometer:-

Mercury thermometer work on the principle of thermal expansion of liquids. In case of mercury thermometer, mercury (liquid)expands when the temperature increases. This rise in the level of mercury gives the temperature readings.

6. Design and Implementation of a Microcontroller Based Digital Thermometer

2.1. The Design.

A thermometer is a device that measures temperature or temperature gradient. It has two important elements; the temperature sensor in which some change occurs with temperature change, and converter which converts this into numerical value. Thermometers are of different type, among which is a digital thermometer. Digital thermometers are temperature sensing instruments that are easily portable, have permanent probes and a convenient digital display. Most digital thermometers and temperature related devices designed and constructed earlier used discrete components (such as timers, counters, decoder drivers etc.) and temperature sensors (such as thermistors etc.) [1][2] Though, some used microcontrollers with external analogue to digital converter (ADC) [3]. However, these devices occupied much space, have more weight, consume much power and are less flexible such that modification of the system requires replacing hardware components. On the other hand, the temperature sensor suffers problems such as non-linearity among others [4]. Meanwhile, for the microcontroller design, a microcontroller with an internal ADC incorporated is required. In this paper, a microcontroller based digital thermometer is designed and constructed. It is based on PIC16F877A microcontroller (as the heart of the system). Figure 1, gives the system block diagram and is in five modules; power supply, temperature sensor, PIC16F877A microcontroller, display and the alarm modules. The temperature sensor (LM35DZ) senses the surrounding or object temperature, the sensed temperature is then being decoded by the PIC16F877A microcontroller and finally the corresponding digital equivalent is displayed (in degree Celsius) on the display unit (7- segment display).

The system (with the aid of a buzzer) also makes an alarm when the temperature reading is 40oC and above. This work shows that microcontrollers can be used as main control element/device to many electronic circuits, providing control, accuracy and flexibility in designs such that, system modification has nothing to do with the hardware part but the software code as opposed to discrete components design. The work also illustrates the elimination of external ADCs in microcontroller designs dealing with analogue signals.

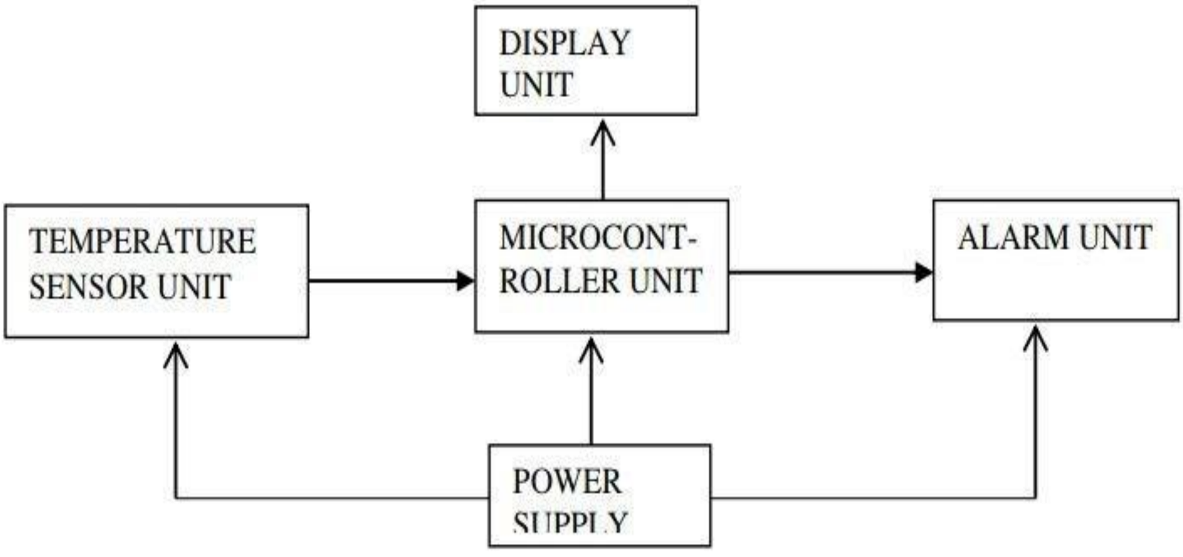


Fig. 1. System block diagram.

Design Methodology The digital thermometer design is in two phases; Hardware and Software (firmware).

2.1 Hardware Design .

The hardware design is divided into five units; power supply, microcontroller, temperature sensor, display and the alarm units. Figure 2 below gives the digital thermometer circuit diagram.

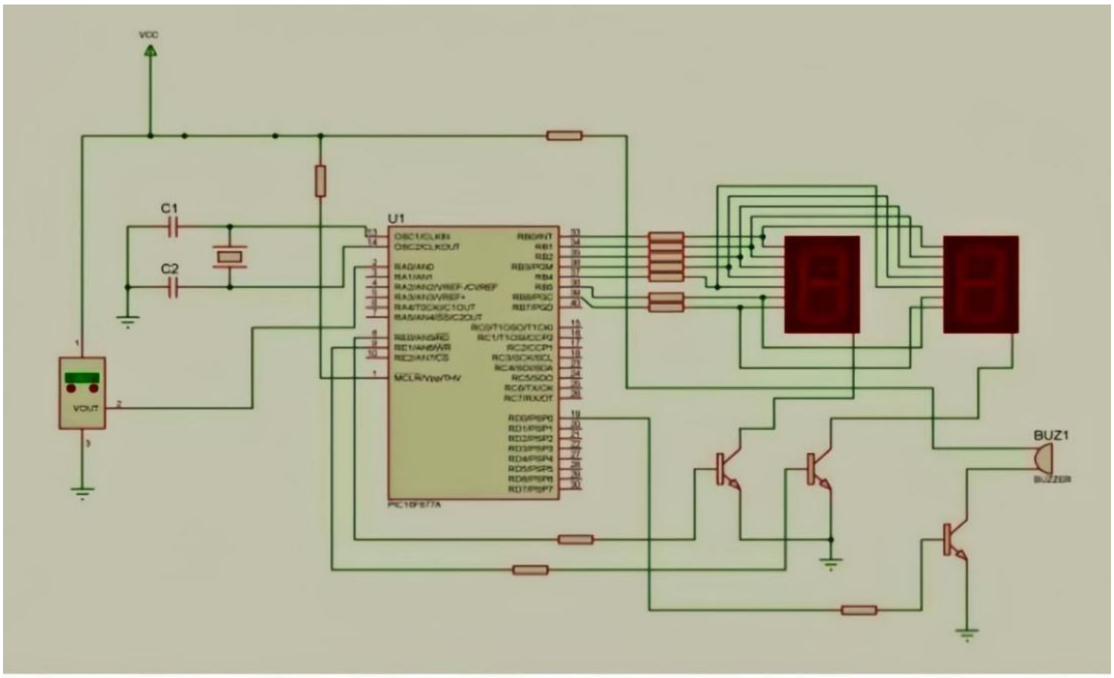


Fig. 2. Digital thermometer circuit diagram

2.1.1 Power Supply unit

The power supply requirement for the design is shown below;

$V = 6V$ [5][6][7]

$$I_L = 300.06mA \text{ , where } I_l = I_{load} = I_{MCLR} + I_{VDD} + I_{BUZZER} + I_{LM35}. - - - - -(1)$$

I_{LM35} = Current through the LM35 (sensor) supply pin (0.06mA). [5]

I_{MCLR} = *Current through the reset pin* (25*mA*). [6]

I_{VDD} = Current through the microcontroller supply pin (250mA). [6]

I_{BUZZER} = Current through the buzzer supply pin (25mA). [7]

A 9V dc battery (Energize 522) [8] is used as the power supply with LM7806IC to regulate the voltage to a steady +6V. The battery makes the device portable and is readily available in the market.

2.1.2. Microcontroller unit.

The microcontroller selected for this work is PIC16F877A. It is a 40-pins dual inline package (DIP), having five ports (A-E), 8- input channels (analogue to digital module), 8k flash program memory and much more [6]. It is chosen due to its in-built analogue-to-digital module, reduced instruction sets (35), among other features [6]. The microcontroller is also readily available in the market. Its diagram and pin connection is shown in fig. 3 below.Quartz crystal is chosen for this work due to its stability. The PIC16F877A oscillator is configured as an on-chip, only requiring the crystal oscillator at pin 13 and 14, with appropriate capacitors C1 and C2 respectively [6]. It is recommended that 15pF capacitor be used each for both C1 and C2 for a clock frequency of 4MHz. The clock frequency (4MHz) is chosen for ease of calculation and perfect timing since; one instruction cycle is equal to four oscillation periods [6]. Therefore, for an oscillator frequency of 4MHz, the execution time will be 1-microsecond. Fig. 4 below gives the crystal oscillator set up diagram.

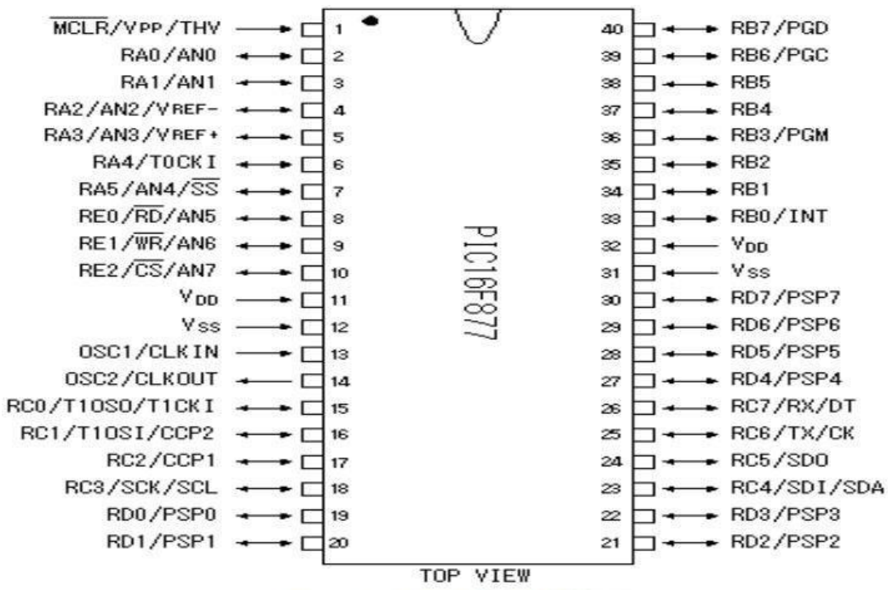


Fig. 3. PIC16F877A [6]

2.1.3. Temperature sensor unit.

LM35DZ [5] of the LM35 precision centigrade, integrated circuit temperature sensor series was selected for this work. Its output is linearly proportional to the Celsius (centigrade) temperature scale, as user does not require any calibration to obtain convenient centigrade scaling [5]. Its linear output [5], low output impedance [5], inherent precision calibration [5], easy interfacing and availability make it the choice for this work. Its output voltage is given by; (1) Where Vout is the LM35 output voltage and T is the temperature in of The output temperature range of LM35DZ is 0 oC to 100 oC [5]. Using eqn.1 above, the output voltage range is 0V to 1V. The LM35DZ voltage supply is given by; $4V \leq Vs \leq 30V$ [5] (2) And the digital thermometer power supply is 6V. Thus, the condition in eqn. 2 above is satisfied.

2.1.4 Display unit.

The display unit displays the sensed temperature in digital form after being processed by the PIC16F877A microcontroller. A seven segment led display (double digit) [9] is used in this work in multiplexed mode. The common cathode type (523E) [9] is used. The LEDs in the seven segment display are operated in forward bias as shown in fig. 5 below. This display type is used due to its high brightness and high contrast, solid state reliability, wide viewing angle, availability and easy interfacing.

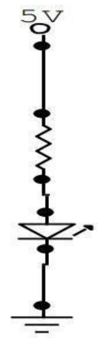


Fig. 5. LED Circuit in Seven Segment Display

$$I_b = \frac{I_{c(sat)}}{h_{fe}} \text{ [10]} \quad (3)$$

$$= 0.2/200 = 1mA$$

$$R_b = \frac{V_{CC} - V_{be}}{I_b} \text{ [10]} \quad (4)$$

$$= (5 - 0.7)/(1 \times 10^{-3}) = 43K\Omega \quad ,$$

$$where\ V_{be} = 0.7V\ for\ silicon.$$

2.1.5. Alarm unit .

A buzzer (EMB-2306L) [7] is used to generate a sound when the sensed temperature is 40 oC and above. This buzzer is chosen due to its low cost, and built-in drive circuitry. The buzzer supply current-limiting resistor R is given by;

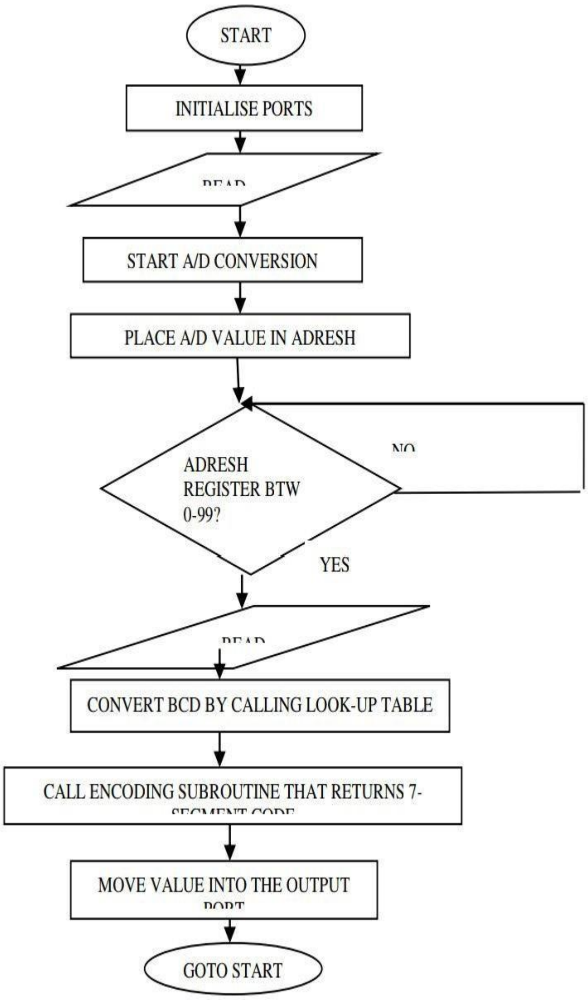


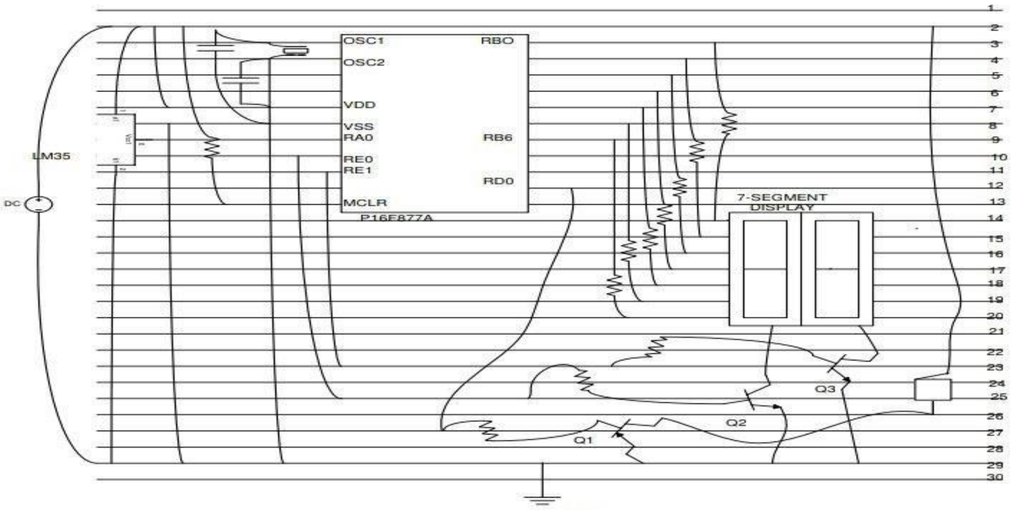
Fig. 6. Program flow chart

2.1.6. Software Design (Firmware).

The firmware design constitutes the program flow chart and the control program codes. The program flow chart is given in fig. 6 below. The system control as well as the digitization of the analogue signal (sensed temperature) is done by the firmware. The source code is written in assembly language and assembled using MPLAB IDE then burnt on to the PIC microcontroller program memory.

2.2. Implementation (Construction)

Before implementing the circuit on a Vero board, the components were tested to confirm their rated values. The components were carefully soldered to avoid damage. Short circuits and continuity test were then carried out on the circuit board. Fig. 7 (a) and (b) below respectively, gives the connections diagram and the system snap during implementation.



(a)

Table 3: Frequency of the difference of temperature in °C between 10 min glass mercury and digital thermometers.

Comparisons	Difference of temperature in °C	Frequency of difference *n* (%)
10 min mercury and digital thermometers	No	19 (19.4)
	0.1	38 (38.8)
	0.2	**28 (28.5)***
	>0.2	**13 (13.3)***

The bold and "*" indicate the frequency of clinical significant.

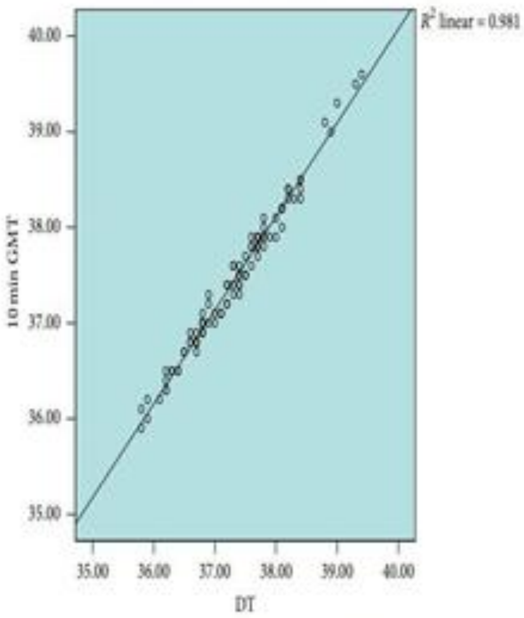


Figure 4: Correlation of 10 min glass-mercury and digital thermometers.

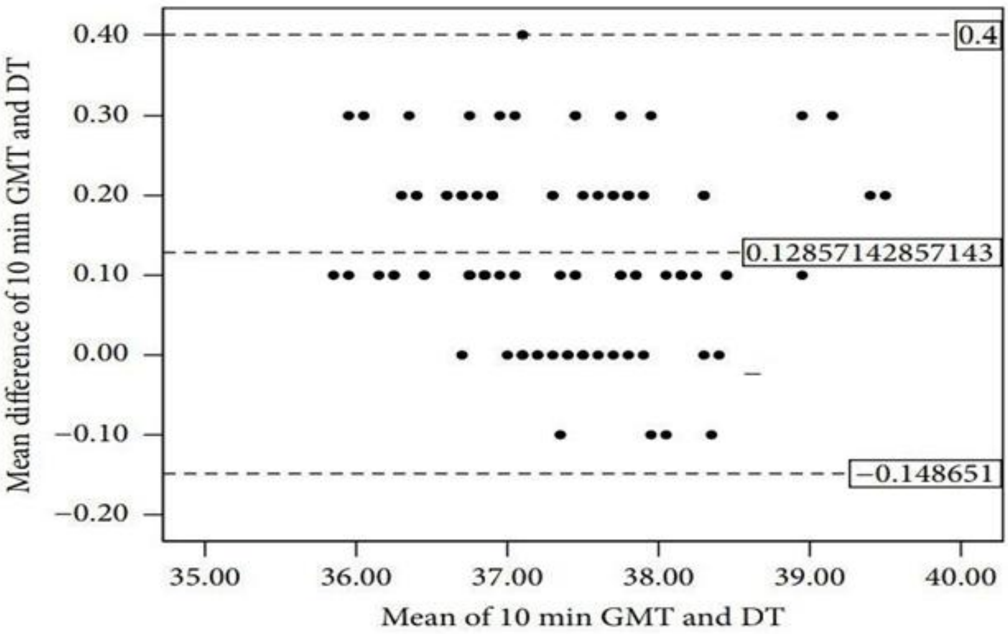


FIGURE 5: Bland-Altman plot of 10 min glass mercury and digital thermometers.

TABLE 1: Sociodemographic characteristics of under-5 children with febrile illnesses in under-5 OPD.

S. number		Variables	Frequency ($n = 98$)	Percentage (%)
1	Age	0–28 days	4	4.1
		29 days–1 years	30	30.6
		1–3 years	34	34.7
		3–5 years	30	30.6
2	Sex	Male	45	45.9
		Female	53	54.1
3	Religion	Orthodox	90	91.8
		Muslim	8	8.2
4	Care giver	Mother	86	87.8
		Father	7	7.1
		Sister/brother	2	2
		Care servant	3	3.1
5	Data collection time	Morning	66	67.3
		Afternoon	32	32.7
6	Taking antipyretic within 30 min	Yes	8	8.2
		No	90	91.8
7	Taking bath within 30 min	Yes	2	2
		No	96	98

Table 2: Mean, SD, and range of temperature results of 10 min glass mercury and digital thermometers.

Thermometers	Observation	Mean ± SD	Median	Range	Minimum	Maximum
10 min mercury	98	37.43 ± 0.77	37.4	3.7	35.9	39.6
Digital	98	37.30 ± 0.78	37.3	3.6	35.8	39.4

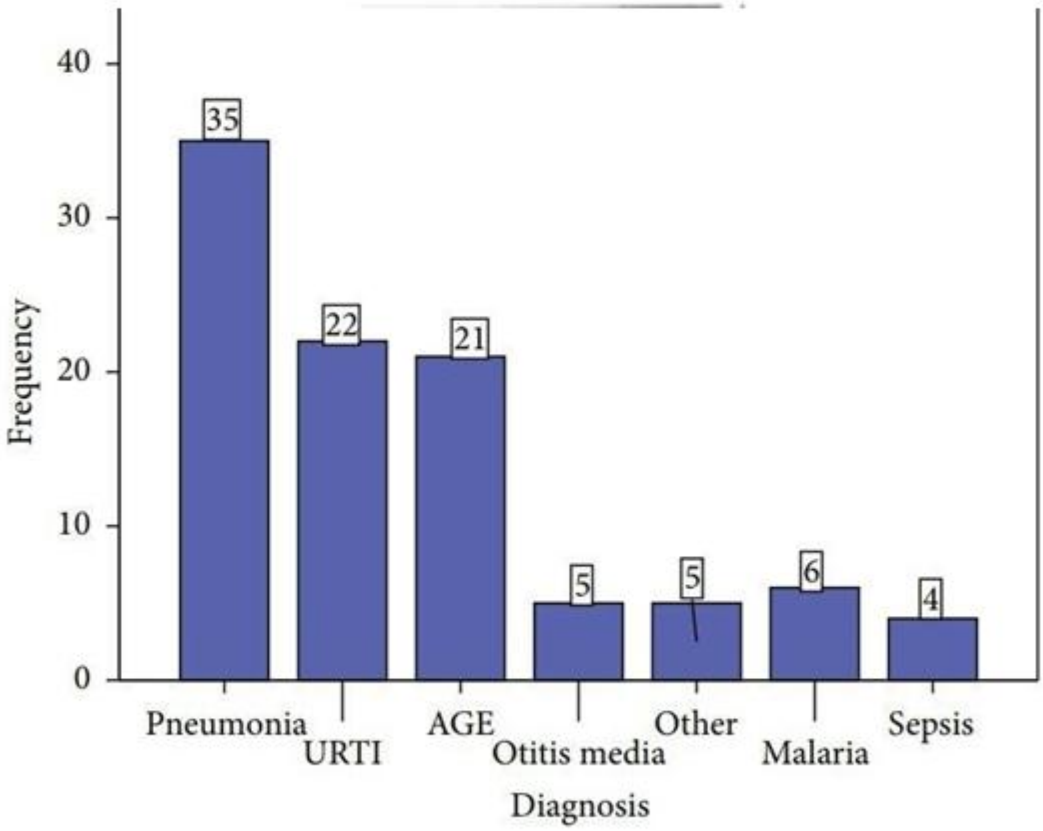


Figure 3: Diagnosis of under-5 children with febrile illnesses in under-5 OPD.

- **Result.**

4.1.1. Sociodemographic Characteristics.

A total one hundred and one study subjects were included in the study, but ninety-eight (97%) of them were analyzed. three were excluded because of their incompleteness and being unreadable. Sixty-six (67.3%) were collected in the morning. Fifty-three (54.1%) were female. Thirtyfour (34.7%) of the children aged from 1 to 3 years. Ninety (91.8%) and 96 (98%) were not taking antipyretic and bath 30 min prior to temperature measure- ments, respectively. For further details, see Table 1.Most of the under-5 children in the study were diagnosed with pneumonia which accounts for 35 (35.7%). For further details, see Figure 3.

4.1.2. Temperature Differences between 10 min GMT and DT.

In this study, one reading was for 10 min glass mercury thermometer and digital thermometer for each study subject. The procedure was carried out for 98 subjects. This resulted in 98 temperature readings for each 10 min GMT and digital thermometer. The mean temperature of 10 min GMT and digital was 37.30 ± 0.78. See Table 2. The maximum and minimum difference of 10 min mer-cury and DT was 0.4∘ C and 0.1∘ C, respectively. But 19 have no difference. Only 13 (13.3%) of the 98 paired measurements of each10 min GMT and DT had temperature difference greater than 0.2∘ C, respectively. For further details, see Table 3.

➢ **Discussion.**

Due concerns about the breakages and envi-ronmental hazards of digital thermometers have evolved with the hope of replacing the glass mercury thermometer. The importance of the speed of application and the ease of use of DT is important in busy clinical area, but accuracy must be a primary concern.

The present study was conducted to find the concordance of the digital thermometer with the glass mercury thermome-ter with thehypothesis that there are statistical significant mean differences in temperature result between 10 min GMT and DT. The participant characteristics of this study were under-5 children who had febrile illness unlike the study conducted in Turkey (healthy infants and healthy young students aged from 18 to 24), India (health neonates), and Malaysia (all age group with illness) [19, 27, 38]. Similarly, this study measured temperature at auxiliary which was consistent with other studies in Turkey, India, and Korea, [19, 27, 39], but not with Malaysia which was on oral site [38]. Most of the previous studies used only statistical test [36, 39–48] unlike this study, which used both statistical and clinical implications in the overall decision of the research hypothesis. The mean difference of 10 min GMT and DT in this study showed a statistical significance ($p < 0.00$).

This finding was supported from the study of Biomedical Instrumentation and Technology which indicates that the improvements in safety, speed, and simplicity of use of the DT have been offset by statistically significant difference. Latman states that “the current generation of electronic, digital clinical thermometers, in general, may not be sufficient to replace the traditional glass/mercury thermometers” [49]. But from the point of clinical importance, the mean difference (0.13) of 10 min and DT of this study was not of clinical significance. 99% of the mean differences were between 0.10 and 0.16, which are not clinically significant.The correlation also showed strong positive correlation ($r = 0.99$) and all the mean differences were also falling in the limit of the agreement. These results were similar to the studies conducted in Iran and USA in which digital thermometers gave the best concordance with mercury thermometers [18, 50, 51]. The variation of temperature between 10 min GMT and DT was not homogeneous (consistent). Furthermore, the mean difference observed between 10 min GMT and DT was not clinically significant, so no compensation for the differences was needed. [28]

But one study found that GMT and DT were clinically and statistically significant with mean difference of 0.278 and $p > 0.05$ [38]. This difference might be because of the route difference, since the study was conducted in oral route in which GMT were highly influenced by ingestion of food prior to 30 min. Similarly, the measurements were not taken simultaneously unlike this study.

4.2.1. Conclusion.

Even though a statistical significance ($p < 0.00$) difference was observed between 10 min GMT and DT, their mean differences were not clinically significant (<0.2∘ C C) or do not differ enough to cause problems in clinical interpretation. Their correlations were also strong positive correlation ($r > 0.75$) and all the mean differences among them were falling in the limit of agreement in Bland-Altman plot. Their variation in temperature is not likely to change any clinical decision. No compensation for the difference is needed since lack of consistent mean differences (homogeneous variations) between GMT and DT was shown. Similarly, their differences were clinically not significant. Statistically, the alternative hypothesis was not rejected. But this statistical significance cannot prejudice the alter-native approach of DT because the clinical insignificances observed were most important (the primary concern). Generally, the strong correlations, good agreements, and clinical insignificances observed make

DT good alternative to the traditional GMT. Similarly, some important disadvan- tages of GMT, such as danger of breakage, potential harm and toxic vapor effects, difficulties in reading the values on the device, possible role in spread of hospital acquired infection, and long dwelling time, and advantage of DT, such as rapid result delivery, improved patient comfort, being an easy and noninvasive procedure, also support this alternative approach. Therefore,

(i) health professionals should use DT for measuring body temperature in under-5 febrile illnesses as it has no clinical significance difference with GMT and has some advantages over GMT (being easy to read, having fast result, and being environmentally friendly) [5, 19]

(ii) researchers should further study the instruments in neonates as clinical significance is different from the present study and the age groups were few. Similarly, the sensitivity may differ from other since their skin integrity is different. Likewise, their concordance in detecting hypothermia should be investigated since the sensitivity may differ.

(iii) Moreover, researchers should repeat the study by using core temperature as the gold standard for com- parison since comparison of DT with GMT may have additive effect of deviation from core temperature.

(iv) FMHACA should focus on DT rather than GMT as it has no clinical significance difference with GMT and have some advantages over GMT (being easy to read, having fast result, and being environmentally friendly) [5, 19].

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