A COMPARATIVE STUDY ON ACCURACY OF DIGITAL THERMOMETER AND MERCURY IN GLASS THERMOMETER IN MEASURING TEMPERATURE IN CHILDREN AGED ONE MONTH TO 12 YEARS IN A TERTIARY REFERRAL CENTRE

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Abstract : OBJECTIVES1. To compare the accuracy of digital thermometer with mercury thermometer in children aged one month to 12 years.2. To determine the average time taken by the digital thermometer to record the temperature.

MATERIALS AND METHODS-DESIGN - Cross sectional study
SETTING- Ward of medical unit V of Institute of Child Health Hospital for Children a Pediatric tertiary care centre.

PERIOD OF STUDY July 2010 to September 2010.

PARTICIPANTS Inclusion criteria- Febrile children aged 1 month to 12 years who are admitted as in-patient in Institute of Child Health Hospital for children, Egmore.

Sample size 92 (based on study by Fadzil et al which shows a 0.480C limits of agreement). MAJOR OUTCOME MEASURES1. Concordance and discordance of digital thermometer with mercury thermometer.2. The average time taken for the digital thermometer to measure temperature.

RESULTSThe mean difference between digital and mercury thermometer recordings is 0.260C (95 CI 0.18-0.34). The correlation coefficient between mercury and digital thermometer recording is statistically significant (R0.976, p0.001). The Bland-Altman test shows that almost all residual values (Estimated observed) are random and the fall within the 95 confidence limits. The difference between estimated and observed mercury value was found to be 0.257(meanSD) (95 CI 0.50372 to 0.50372). The average time taken by the digital thermometer to record the temperature was 88.03 (95 CI 54.58 to 121.49)

CONCLUSIONSDigital thermometer is as accurate as mercury in glass thermometer in recording temperature. The average time taken (in seconds) by the digital thermometer to record temperature is 88.03 17.07.

Keyword : temperature, digital thermometer, children

INTRODUCTION:
Fever is one of the most common and also a most important sign in children (1). Fever is a controlled increase in body temperature over
It is a common cause of parental concern and anxiety. Despite the fact that temperature measurement in children seems so simple – a wide variety of devices are available to record fever from skin, oral or rectal mucosa or the tympanic membrane. The definition of fever depends on precise temperature recordings. An appropriate recording of the absence of fever reassures both parents and health care providers thereby avoiding the need for inappropriate medical consultations and investigations. It is, therefore, essential that the measurement of fever be accurate and reproducible.

However, the following are generally accepted values:

- Rectal temperature above 100.4°F (38°C)
- Oral temperature above 99.5°F (37.5°C)
- Axillary (armpit) temperature above 99°F (37.2°C)
- Digital pacifier temperature above 100°F (37.8°C)
- Ear temperature above 100.4°F (38°C) in rectal mode or 99.5°F (37.5°C) in oral mode

There are many types of thermometers. The conventionally used thermometer is mercury in glass thermometer. They are thin glass tubes filled with a small amount of mercury—a special metal that's a liquid at ordinary temperatures. When mercury gets hotter, it expands (increases in size) by an amount that's directly related to the temperature. So if the temperature increases by 20 degrees, the mercury expands and moves up the scale by twice as much as if the temperature increase is only 10 degrees(4). A scale is marked on the glass with which the temperature is read. Rectal temperature measured using mercury thermometer is the gold standard. But the main disadvantage of mercury is that it is an environmental hazard. Hence the Canadian Paediatric Society no longer recommends the use of mercury thermometers. (5)

Electronic or digital thermometers are based on the idea that the resistance of a piece of metal (the ease with which electricity flows through it) changes as the temperature changes. As metals get hotter, atoms vibrate more inside them making it is harder for electricity to flow, and the resistance increases. Similarly, as metals cool down, the electrons move more freely and the resistance goes down. At temperatures close to absolute zero, the lowest theoretically possible temperature of 273.15°C or 459.67°F, resistance disappears entirely in a phenomenon called superconductivity (4). The measured temperature is displayed as a number (in Fahrenheit) in the panel which can be easily read. The main disadvantage is its cost. Tympanic thermometers measure the thermal radiation emitted from the Tympanic Membrane(TM) and the ear canal, and have therefore been called infrared radiation emission detectors (IRED). Because the amount of thermal radiation emitted is in proportion to the membrane’s temperature, IRED accurately estimates TM temperature. In contrast with other sites of temperature measurement, the TM’s blood supply is very similar in temperature and location to the blood bathing the hypothalamus, the site of the body’s thermoregulatory centre. It is, therefore, an ideal location for core temperature estimation. Otitis media or earwax have been shown to change tympanic readings significantly. (4) Infrared arterial temperature can be measured with a device that is passed over the front of the forehead to the temporal area. This relatively new method of body temperature measurement has been shown to be more accurate than tympanic thermometry and better tolerated than rectal thermometry.
Temporal artery thermodometry may be a promising tool for screening children at low risk in the ER but cannot yet be recommended for home use or hospital use when definitive measurements are required. The recommendations of the Canadian Paediatric Society are

**Recommended temperature measurement techniques**

Though mercury thermometer remains the gold standard, considering its disadvantages that it is not environment as well as user friendly, if digital thermometer is as accurate as mercury thermometer, it can be used for recording the temperature in clinical practice as well as at home. Most studies comparing digital and mercury in glass thermometer were done in adults and there are very few studies done in pediatric population. Hence this study was done to compare the accuracy of digital and mercury thermometer.

**METHODS:**

This descriptive study was conducted in the medical unit V ward of the Institute of child health and hospital for children, Egmore, Chennai from July 2010 to September 2010. Sample size of 92 was calculated based on previous study which shows a 0.48°C limits of agreement.

Children between one month and twelve years of age who are admitted in the ward whose caregiver’s complaints of fever or children found to be febrile on examination were included in the study. Basic demographic details of all eligible children were noted. After obtaining informed consent from the caregiver, temperatures of all eligible children were recorded using mercury and digital thermometer placed in each axilla simultaneously. Mercury in glass thermometer was placed in axilla for 5 minutes as per IMNCI guidelines (7) and temperature was noted in Celsius to the accuracy of 0.1°C.

The digital thermometer was removed from the axilla after the beep and the temperature displayed was noted. The time taken for the temperature to be displayed was noted using a stop watch. The temperature displayed in Fahrenheit was converted to Celsius using the formula:

$$T_c = \frac{(T_f - 32) \times 5}{9} \quad T_c = \text{Temp. in Celsius}$$

$$T_f = \text{Temp. in Fahrenheit}$$

Date and time of temperature measurement was also noted. The mercury as well as digital thermometers used were manufactured by Hicks thermometers India limited. Recommendations given by the manufacturer were followed while using the thermometers. Mean and standard deviation of demographic data, recordings, the difference between both recordings and time taken were calculated. Correlation coefficient was calculated using Karl Pearson correlation graph. Limits of agreement were calculated using Bland Altman test after fitting regression equation.

**RESULTS:**

Temperature recording was done in 92 children of age between 2 months to 12 years using mercury in glass and digital thermometers. Mean age of children screened was 50.2 months (50.2±42.15). 62(67.4%) of them were male and 30(32.6%) were female. The mean, standard deviation, minimum and maximum values for mercury and digital thermometer recordings were 37.89, 0.839, 36, 39.2 and 37.63, 0.862, 35.6, 39.2 respectively. The difference between digital and mercury thermometer recordings in each child was calculated. The mean, standard deviation, minimum and maximum values of the difference were 0.26, 0.04, -0.9
and 1.8 respectively (TABLE I). On analyzing the temperature recording by mercury in glass thermometer and digital thermometer using Karl

Pearson correlation scatter plot, the correlation coefficient ($r$) was found to be 0.976 with corresponding p value of $<0.001$, which is highly significant (FIGURE 1).

<table>
<thead>
<tr>
<th>Age</th>
<th>Recommended technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth to 2 years</td>
<td>1. Rectal (definitive)</td>
</tr>
<tr>
<td></td>
<td>2. Axillary (screening low risk children)</td>
</tr>
<tr>
<td>Over 2 years to 5 years</td>
<td>1. Rectal (definitive)</td>
</tr>
<tr>
<td></td>
<td>2. Axillary, Tympanic (or Temporal Artery if in hospital) (screening)</td>
</tr>
<tr>
<td>Older than 5 years</td>
<td>1. Oral (definitive)</td>
</tr>
<tr>
<td></td>
<td>2. Axillary, Tympanic (or Temporal Artery if in hospital) (screening)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thermometer</th>
<th>Observations (n)</th>
<th>Mean ($^\circ$C)</th>
<th>Standard Deviation</th>
<th>Minimum ($^\circ$C)</th>
<th>Maximum ($^\circ$C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury in glass</td>
<td>92</td>
<td>37.89</td>
<td>0.830</td>
<td>36</td>
<td>39.3</td>
</tr>
<tr>
<td>Digital</td>
<td>92</td>
<td>37.63</td>
<td>0.862</td>
<td>35.6</td>
<td>39.2</td>
</tr>
<tr>
<td>Difference between digital and mercury recordings</td>
<td>92</td>
<td>0.26</td>
<td>0.04</td>
<td>-0.9</td>
<td>1.8</td>
</tr>
</tbody>
</table>

**TABLE –II: REGRESSION COEFFICIENTS (DEPENDENT VARIABLE: READING IN M.T(C))**

<table>
<thead>
<tr>
<th></th>
<th>Regression Coefficient</th>
<th>t</th>
<th>P value</th>
<th>95% CI for B Lower Bound</th>
<th>95% CI for B Upper Bound</th>
<th>Adj. R Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>2.956</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digital Reading</td>
<td>0.927</td>
<td>29.50</td>
<td>&lt;0.001</td>
<td>0.864</td>
<td>0.969</td>
<td>0.905</td>
</tr>
</tbody>
</table>

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Regression coefficient and Bland-Altman test were employed to depict how well the digital thermometer reading predicted the mercury in glass thermometer reading (TABLE II). The fitted regression equation is 

\[ \text{Mercury reading} = 2.956 + 0.927 \times (\text{Digital reading}) \]

The fitted model shows that about 90% of the variation is explained by the digital reading (Adj. \( R^2 = 0.905 \)). It is also statistically significant (\( P<0.001 \)). The mean, standard deviation upper limit and lower limit for the difference of estimated and observed mercury reading is 0.00, 0.25, +0.50372 and -0.50372 respectively. The Altman Bland chart shows that almost all residual values (Estimated – observed) are random and the fall within the 95% confidence limits (FIGURE 2). The average time taken by the digital thermometer to record the temperature was 88.03 seconds (95% CI –54.58 to 121.49). The minimum and maximum time taken were 56 and 140 seconds respectively.

**DISCUSSION:**

The results of the study show that digital thermometer agreed well with the mercury in glass thermometer. The difference between digital and mercury thermometer temperature recordings noted in our study was similar to that study done by Shank et.al (12) whereas the study done by Kongpanichkul A et.al (13) shows a higher 95% CI. This could be due to the fact that, in that study digital thermometer reading was compared with mercury reading recorded rectally. The mean duration taken to record the digital temperature reading in our study was more than that reported by Ray et.al (14), this could be because of the fact that the study was done on neonates who need minimal restraint for the procedure. Though mercury in glass thermometer is the gold standard for recording temperature, there are some disadvantages. Mercury is not available in India, it is imported hence it is a drain on the country's foreign exchange. India imported almost 720,000 thermometers, costing USD 1.77 million in the year 2007-08 (5). Mercury content of a thermometer ranges from 0.5 to 3 grams. Though the amount may seem small, it is enough to pollute a small lake. Mercury waste from broken fever thermometers is significant. For instance, thermometers used and broken in India's health care sector emit an estimated 2.4 metric tons of mercury per year (5). When released into the air mercury may stay in the atmosphere for up to a year, and is transported and deposited globally. It is interesting to note that, currently products containing mercury are used in large scale in hospitals and clinics and still the waste generated from these units are not considered as hazardous waste and rather classified as biomedical waste. A draft notification was circulated by the Ministry of Environment and Forest (MoEF) in 2000 for a phased elimination of mercury from consumer products, but so far action taken is minimal.

Health Care without Harm Europe (HCWH), is dedicated to transforming the health care industry worldwide, without compromising patient safety or care, so that it is ecologically sustainable and no longer a source of harm to public health and the environment with the support of NGOs from many countries including India (Toxics Link). On the contrary digital thermometer is environment-friendly. It is also easy to use (easily readable) and has no subjective and inter observer variations and hence has a high reliability. It is also less time consuming as against mercury thermometer which is recommended to be placed for full 5 minutes according to IMNCI guidelines.
Since accuracy of digital thermometer is comparable to mercury thermometer besides being less time consuming and non-toxic, digital thermometer can replace mercury thermometer (which still remains the gold standard) in recording of temperature at home and in clinical practice.

CONCLUSION:
The digital thermometer is as accurate as mercury in glass thermometer for recording temperature in children aged one month to twelve years. The average time taken by the digital thermometer for recording temperature is 88.03 seconds.

KEY MESSAGES:
What is already known on this topic?
Digital thermometer is commonly used for recording temperature.

What this study adds:
Digital thermometer is as accurate as mercury in glass thermometer and it is less consuming.

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Figure 1 Karl Pearson Correlation