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Abstract

Introduction. Body temperature is measure in all setting of primary health care. There are some thermometers for use, but the results of their measurements are controversial. Patients and methods. We made measurements of body temperature with cutaneous, ear, digital axillary and mercurial axillary in 100 children under 18 years old that attended a private ambulatory pediatric health care; they were rest 15 minutes and then we made the measurements, two times for one researcher and another time for a different researcher. The time between measurements were 15 minutes. We calculated validity and repeatability in cutaneous, ear and digital axillary thermometers compared with mercurial axillary; we obtained r Pearson and regression lineal equation. We calculated Kappa for the agreement intra-researcher and inter-researchers. Results. Sensitivity was low (<70%) for cutaneous and ear thermometers, but it was high for digital axillary. Predictive positive value was high for digital axillary thermometry compared with mercurial axillary (>90%). r de Pearson was excellent (>0.90) between digital axillary and mercurial with regression lineal equation significative (p<.05). Kappa was higher, 0.89 y 0.90 for digital axillary and mercurial axillary thermometry. Conclusion. In our sample, digital axillary thermometer measured the body temperature more similar that mercurial axillary thermometer.

INTRODUCTION

Measuring body temperature is routinely performed in health care services, and can use different measuring instruments. The use of body temperature measurement and monitoring, is the oldest references in the first or second century BC and in 1592 Galileo manufactured a thermometer.¹

Technological advances have led to the development of thermometers for measuring human body temperature, faster and with fewer health risks than mercury thermometers. The most used thermometers two decades ago wer the mercury, axillary, oral or anal and then developed digital thermometers for axillary, oral or rectal; after, otic infrared thermometers were developed and later skin infrared thermometers.

The measurement of body temperature should be accurate, valid and reliable, especially in children, as body temperature rises in them, may be associated with the presence of seizures, dehydration and other complications; in adults can lead to metabolic instability if there is an underlying disease. There are few scientific publications about the validity and reliability of the otic and cutaneous infrared thermometers, used in humans.

Infrared thermometer otic is widely used in health care, mainly due to its speed of measurement (1-2 seconds)² and cutaneous infrared thermometer does not come into contact with skin of the subject and its measurement is fast (3-4 seconds). Axillary digital thermometer takes about 3-4 minutes to give a reading of body temperature and axillary mercury thermometer takes 5 minutes to give a reading, and also depends on the observer's visual perspective as the mercury column that should be read on Celsius scale.

There is little published evidence of clinical benefit from otic or cutaneous thermometry.²³⁵,⁶

Fever was defined as oral temperature of 37.8°C.¹ It is the
result of the immune response to an aggression, which release cytokines (pyrogens), mainly interleukin 1 (IL-1) and interleukin 6 (IL-6) and tumor necrosis factor (TNF). These act on the hypothalamic thermoregulatory center, releasing prostaglandins, mainly E2 (PGE2), responsible for the increase in body temperature.

The traditional measurement of body temperature, with mercury thermometers axillar, oral or anal is rejected, mainly by children, teenagers and some parents. With the development of the otic and skin infrared thermometers are achieved fast and safe measurements, but there is little evidence of its validity and reliability.

Padilla in Mexican children and adolescents, measurement of oral mercurial temperature gave an average of almost 0.5 °C higher than ear measurements and sensitivity, specificity, positive predictive value and negative for otic thermometry compared with oral mercury, were 50%, 100%, 100%, and 87.2%, respectively.

In Texas, Varney y col., showed that in the elderly, the rectal temperature measurement identified more precisely hyperthermia than otic measurement; instead, Sehgal, during 2002 did not find differences between the measurements with rectal and otic thermometers.

Craig y col., in a meta-analysis comparing otic with rectal thermometry, reported that agreement was low, maybe for the heterogeneity in measurement equipment for otic thermometry.

León at al., found that the agreement between otic and mercurial axillary thermometry was good (r=0.8) in patients admitted to the intensive care unit.

We are therefore interested in comparing the measurement of body temperature with skin infrared thermometer, infrared otic, digital axillary and axillary mercury in children of all ages, that attend to a Pediatric Primary Care Center.

**MATERIAL AND METHODS**

Protocol was reviewed and approved by Research and Bioethics Committees of The School of Medicine of University of Celaya.

Study design. Cross-sectional, analytic, in a private pediatrician clinic in Celaya, Gto. The Universe was the children that attended between January 10th and June 15th in 2011.

Subjects. We included all children, from newborn to 17 years and 11 months, that attended the pediatric clinic and whose parents accepted to participate in the study, until the simple sizes is completed. We excluded children whose parents did not accepted to participate.

Anthropometry was performed according to the age on digital scale for babies, neonates and infants without clothing and height was measured in the supine position with Seneca infantometer; in older children we used a scale with altimeter to measure weight and stature, with children without shoes and cloths.

Body temperature measurements were performed three times with each thermometer, twice by the same investigator and the third time, by a different investigator, while blinded to the first two measurements. The interval between each measurement and the next was 10 minutes.

Measuring body temperature with the infrared thermometer skin, was performed using a Microlife FR 1DM1 skin thermometer, the subject was at rest in the waiting room for 15 minutes turn on the thermometer, and is placed 0.5 cm from the skin of the forehead above the left eyebrow and records the measurement is displayed the alarm after completion of the measurement.

The otic temperature measurement was performed with an infrared thermometer Omron Gentle Temp Model MC-505, a disposable sheath placed over the sensor and this was introduced into the left external canal and the pinna is pulled back and above, and measuring the temperature record was displayed on the screen after the alarm completion of the measurement.

For measuring body temperature with digital thermometer axillary digital thermometer was used axillary Microlife MT 3001, the thermometer was placed with the sensor in contact with the skin of the armpit and turns on, waiting until the alarm sounds corresponding final reading.

Mercurial axillary body temperature was measured with a mercury axillary thermometer, shake the thermometer until the mercury is all in the tank. Place the mercury reservoir in contact with the skin of the right armpit and leave for 5 minutes and then is read in °C.

For all measurements the recordings were made in degrees
Hyperthermia was defined as measuring temperature of 38 °C or more.

Sample size. Expected a correlation index of Pearson from 0.8 between otic and mercurial axillary thermometry, with 95% of precision and 90% of power, the minimum simple size is 10 (Epidat 3.1 2006, Xunta de Galicia y OPS). We studied 100 children.

Statistical analysis. We did analysis of the validity (sensitivity, specificity, predictive values) between the otic, skin, digital axillary and mercurial axillary thermometry as the gold standard.

The reliability intraobserver and interobserver were calculated by Kappa, otic, skin and digital axillary compared with axillary mercurial.

Correlation index Pearson’s r is calculated, and linear regression equation between the results of the otic and mercurial thermometry, skin and mercurial thermometry and digital and mercurial thermometry.

For the statistical significance of the measurements, the alpha value was set at 0.05.
All statistical calculations were performed with STATA 10.0® (Stata Corporation, USA).

RESULTS

Our sample consisted of 100 children with similar gender distribution and predominantly urban residence (Table I).

Comparing skin with mercurial axillary thermometry, we found that the sensitivity, specificity and predictive values are similar in the three measurements; the mean of sensitivity was 56.42%; mean of specificity was 97.66%; mean of positive predictive value was 90.74% and mean of negative predictive value was 85.02% (Table II). Skin thermometer detected fever (38 °C or more) in only 56.42% of those detected by mercurial thermometer, and 90.74% of those who actually have high temperature.

Figure 2
Table II Cross-tabulation between three measurements with skin and mercurial axillary thermometers, Celaya, 2011 (n=100)

Comparing the otic with mercurial axillary thermometer, the sensitivity was 61.37%, 96.30% specificity, positive predictive value 86.81% and negative predictive value 86.27% (Table III). The otic thermometer detected 61.37% of subjects with fever and 86.81% of the cases detected by the thermometer otic, had fever.

**Figure 3**
Table III Cross-tabulation between three measurements with otic and mercurial axillary thermometers, Celaya, 2011 (n=100)

<table>
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<th>Parameters</th>
<th>Measurements</th>
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<td>Sensitivity (%)</td>
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</tr>
<tr>
<td>Specificity (%)</td>
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</tr>
<tr>
<td>Positive predictive value (%)</td>
<td>08.95</td>
</tr>
<tr>
<td>Negative predictive value (%)</td>
<td>08.61</td>
</tr>
</tbody>
</table>

To measure the reliability with Kappa, with skin thermometry, intra-observer reliability is 0.7 and inter-observer is 0.76, considering both reliability as well; for otic thermometry, intra-observer Kappa is 0.81 considered good and inter-observer is 0.66, with regular reliability; for digital axillary thermometry, Kappa intra-observer was 0.89 and inter-observer 0.87, both considered as excellent, for the mercurial axillary, intra-observer kappa was 0.90 and inter-observer 0.87.

Correlating measurements between skin and mercurial axillary thermometers, correlation index, Pearson’s r, was regular in the three measurements, the t test to look for linear relationship between both thermometers was statistically significant (p <0.05) in the three measurements (Figure 1).

**Figure 4**
Table IV Cross-tabulation between three measurements with digital axillary and mercurial axillary thermometers, Celaya, 2011 (n=100)

<table>
<thead>
<tr>
<th>Parameters</th>
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<tbody>
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<tr>
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<td>Positive predictive value (%)</td>
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<tr>
<td>Negative predictive value (%)</td>
<td>08.61</td>
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</tbody>
</table>

Between the mercurial thermometer otic and axillary, the correlation coefficients were good (> 0.7) and the three measurements, the t value for testing a linear relationship was statistically significant (p <0.05) (Figure 2).
From digital axillary and digital mercurial, the Pearson correlation indices were excellent (> 0.9) and the three measures t tests, show a linear relationship (p < 0.05) (Figure 3).

DISCUSSION
Our sample is by availability and the results may not generalize to the population under 18 years old from Celaya, Gto.

Being blinded to the body temperatures measured in the first two measurements, it avoid bias of the observer. Also standardized measurement procedures with each thermometer help to avoid measurements mistakes.

The sample size is sufficient, since waiting for a Pearson r of 0.8 should be the minimum size of 10 children, but our Pearson’s r was 0.9 and we studied 100 children under 18.

The skin thermometer offers the advantages of fast measuring (1-3 seconds) and the infrared sensor is not in contact with the skin; for the measure is appropriate with otic thermometer, the sensor should be directed to the tympanic membrane, this is achieved by correcting the direction of the external ear canal, pulling the pinna back and up, also measures body temperature quickly (1-3 seconds) and must use a disposable cap for the sensor. Digital axillary thermometer has a disadvantage that measures body temperature in 3-5 minutes depending on
temperature for each child.

Hausfater\(^7\), found a positive predictive value of 0.10 for the comparing skin thermometer with otic thermometer; in our study, skin thermometer obtained 56.42% sensitivity, positive predictive value 90.74%. This difference may be due to skin thermometer model used in each study.

Although a meta-analysis showed that axillary thermometry shows low correlation with body temperature and it is better rectal thermometry\(^5\), we used the axillary thermometry because at present, many parents who take children to medical care do not accept the rectal thermometry and neither do the children and adolescents, for body temperature measurement.

Craig et al., in a systematic review of 44 studies comparing the axillary and otic thermometry, reported that the differences between measurements are small, the confidence intervals are wide, so it shows that there is not a good correlation between both methods\(^5\). In our study, shows good correlation (r > 0.7) between otic and mercurial axillary thermometry (Figure 2) but low sensitivity and good positive predictive value (Table III).

Dodd et als., reported for the comparison between otic and axillary thermometry, a pooled sensitivity of 63.7% 9
61.37% very similar to the sensitivity found in our study (Table III).

According to the values obtained for sensitivity, specificity and predictive values, the thermometer that show better results of the measurements of body temperature is the digital axillary comparing with mercurial axillary thermometer (Tables II, III and IV). It also shows the highest reliability, as measured by Kappa, and better correlation between both measurements (Figure 3).

One of the difficulties in analyzing the validity and reliability of the different thermometers, is the great variety of models, for our study we selected most common models available to health professionals and families in Mexico.

**CONCLUSION**

Digital axillary thermometry is the best choice for measuring body temperature compared with the skin and otic temperature measurement.

Otic and skin thermometry is quick and secure, but shows less validity and reliability that digital axillary thermometry.

**References**


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