

A comparative study of rectal tympanic and axillary thermometry in febrile children under 5 years of age in Nigeria

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Background: Fever alone accounts for over 25% of paediatric emergency room consultations. Accurate determination of temperature is critical for the management of sick children by both parents and health care-providers.

Aims and Objectives: To compare simultaneous measurements of temperature measured by the rectal, axillary, and tympanic routes in children under 5 admitted to the University of Ilorin Teaching Hospital.

Methods: 400 children under 5 years of age with a rectal temperature of $\geq 38.0^{\circ}\text{C}$ were recruited consecutively into the study. Rectal and axillary temperatures were measured using digital thermometers. Tympanic measurements were undertaken with an infrared tympanic thermometer. All measurements were made simultaneously and compared.

Results: Mean (SD) rectal temperature was $38.8 (0.7)^{\circ}\text{C}$, and mean (SD) tympanic and axillary temperatures were $38.7 (0.7)^{\circ}\text{C}$ and $38.1 (0.7)^{\circ}\text{C}$, respectively. There was no significant difference between rectal and tympanic temperatures ($P=0.14$), and a strong correlation was identified between values from these two sites ($r=0.91$). At 91.5%, the sensitivity of tympanic thermometry in determining fever was higher than that of axillary measurements (54.0%). A mathematical relationship was demonstrated between rectal/tympanic temperatures and between rectal/axillary temperatures as follows:

Rectal temperature ($^{\circ}\text{C}$) = $6.03 + 0.85 \times \text{Mean tympanic temperature } (^{\circ}\text{C})$

Rectal temperature ($^{\circ}\text{C}$) = $11.7 + 0.71 \times \text{Axillary temperature } (^{\circ}\text{C})$

Conclusion: In febrile children, tympanic temperature better reflects rectal temperature than does axillary temperature; tympanic temperature should therefore be measured when there are no contra-indications for its use.

Keywords: Temperature, Fever, Tympanic, Rectal, Axillary

Introduction

Fever is one of the most frequently encountered paediatric problems, accounting for 25% of visits to paediatric emergency rooms.¹⁻³ It represents a perception of an elevated temperature, and, in clinical practice, it is an important sign of a current illness.⁴ Objective definitions of fever are based on development of a variety of thermometers and the identification of different sites for valid measurement of body temperature. Thus, there is no single temperature recording that can be labelled 'normal body temperature' but, rather, it depends on the site of temperature measurement.⁴ Types of thermometers in use over the years include: liquid-in-glass thermometers (mercury or spirit), thermistor-based electronic clinical thermometers, liquid crystal indicator-based thermometers, radiometer-based methods

for temperature reading in the ear canal and chemical thermometers.⁵

The gold standard for core temperature measurement is by a thermistor inserted into the pulmonary artery.⁶ Other sites for accurate measurement of core temperature include the oesophagus and urinary bladder.^{3,7} However, temperature measurements in these organs are laborious, requiring specialised equipment and personnel, and thus are used only in experimental situations.^{3,7}

Rectal measurements have long been regarded as the most practical and accurate means of obtaining routine estimates of core temperature.¹ Rectal temperatures are fraught with numerous challenges which include^{2,6,8} being slow to change in relation to changing core temperature, being affected by the depth of insertion of the thermometer, conditions affecting local (ano-rectal) blood flow, and the presence of stool in the rectum. Rectal perforation has been described occasionally. Without proper

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sterilization techniques, rectal thermometry has the capacity to spread contaminants commonly found in stool.^{6,9} In children, however, axillary temperature, which is easier to measure and more hygienic than oral or rectal measurements, has been found to be an inaccurate reflection of core body temperature.^{10,11} Oral thermometry relies on the mouth remaining sealed, with the tongue depressed for 3–4 minutes, which is difficult for young children.⁶ This method of temperature measurement cannot be used in pre-school children or, indeed, in the unconscious or uncooperative patients.⁶ Tympanic thermometers measure the thermal radiation emitted from the tympanic membrane (TM) and the ear canal, which are perfused by the tympanic artery, a branch of the internal carotid that also supplies the thermoregulatory centre (hypothalamus).^{6,12} Reports of their accuracy are conflicting.^{10,13,14}

This study compares simultaneous measurements of temperature by the rectal, axillary and tympanic routes in febrile children under 5 years of age, and determines their degree of agreement and the mathematical relationship (if any) between measurements from these various sites.

Subjects and methods

Study population

This was a prospective, cross-sectional study. Patients were recruited from the emergency paediatric unit of the University of Ilorin Teaching Hospital, Ilorin, Kwara State.

Sample size determination

The minimum sample size was calculated using the Andrew Fisher formula¹⁵ with a proportion in the target population of 50% which gives a maximum sample size and a degree of accuracy of 0.05. The calculated minimum sample size of 384 was rounded up to 400.

Study protocol

Subjects were recruited consecutively over a 4-month period (August–November) in 2009. All children between 2 and 59 months of age admitted to the emergency paediatric unit with a history of fever and in whom the admitting rectal temperature was $\geq 38.0^{\circ}\text{C}$ ¹⁶ were recruited. Children with clinical parameters suggestive of shock, malnourished children and children who looked toxic, gravely ill or *in extremis* were excluded. The age and gender of each child were recorded. Temperature measurements and recordings were carried out by the investigators and trained assistants. Rectal and axillary temperatures were taken using a U-mec[®] digital thermometer. Axillary measurements were made by putting the digital thermometer in the right axillary pit where it was held firmly in place by assisting the child to adduct the right upper limb on the upper trunk. Measurements were recorded

after 5 minutes with the thermometer in place. Aural temperatures were measured using a Braun Welch Allyn Thermoscan[®] PRO 4000 with Intelliscan[®]. To measure temperature via the tympanic membrane, the ear canal was straightened by pulling the pinna downwards and backwards in children <3 years, but upwards and backwards in older children.¹⁷ With the ear tugged correctly, the probe tip was inserted into the external auditory canal, pointing at the midpoint between the eyebrow and sideburn on the contralateral side, and temperature was obtained by depressing the measurement button on the device until a beep indicated measurement.¹⁷ The displayed results were recorded in $^{\circ}\text{C}$ approximate to one decimal point. The procedure was repeated in the other ear. Rectal temperatures were measured by inserting a slender KY jelly-lubricated U-mec[®] digital thermometer into the rectum. The thermometer was inserted up to a maximum distance of three centimetres and was read after being in place for at least 3 minutes.⁵

Statistical analyses

Data entry and analysis were undertaken using EpiInfo version 6. Measures of central tendency and dispersion of quantitative variables were used. Mean, standard deviation and range of the temperature measurements were obtained. The sensitivity of tympanic and axillary measurements at various cut-offs of rectal temperature was calculated. Temperatures from various sites were compared using correlation scattergrams. Correlation of the various measurements was determined using Pearson's correlation coefficient, and confidence intervals were determined. The Bland–Altman plot was used to assess the absolute differences between rectal and axillary and rectal and tympanic temperatures. Regression line analysis was used to provide the mathematical relationship between the various temperature measurements. $P < 0.05$ was considered significant.

Ethical clearance

Ethical clearance was granted by the University of Ilorin Teaching Hospital Ethical Review Committee. Informed consent was obtained from the caregivers after explaining the study protocol.

Results

A total of 400 children aged 2–56 months were recruited. Mean (SD) age was 25.6 (16.8) months and 23.8% were infants <12 months. Fifty-nine per cent (236) of the subjects were male and the male:female ratio was 1.5 : 1. Four hundred sets of rectal, axillary, and tympanic temperature measurements were recorded. Table 1 provides a summary of temperature measurements from all sites.

Mean (SD) rectal temperature was 38.8°C (0.6), and the mean of the average tympanic temperatures was 38.7°C (0.7). Tympanic membrane temperature

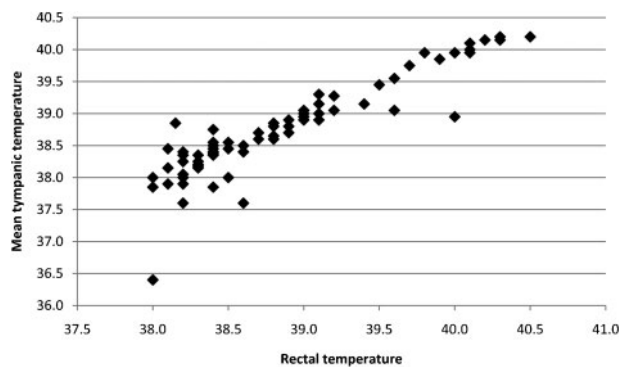


Figure 1 Correlation scattergram of paired rectal and mean tympanic temperatures (°C)

measurements were reproducible. The mean (SD) difference between left and right tympanic temperatures was 0.019°C (0.1) (Table 2), but the difference is not statistically significant. There was strong correlation between the right and left tympanic temperature measurements ($r=0.99$, $P<0.05$). The average of the left and right tympanic measurements was used for subsequent analysis.

The mean (SD) difference between rectal temperatures and mean tympanic membrane readings was 0.1°C (0.3) (95% CI 0.08–0.14). On the other hand, the mean (SD) difference between rectal and axillary temperatures was 0.8°C (0.4) (95% CI 0.71–0.80). Furthermore, in all cases and at all temperatures, rectal measurements correlated more closely with mean tympanic temperature ($r=0.91$, 95% CI 0.89–0.93) than with axillary measurements ($r=0.82$, 95% CI 0.78–0.84). Figures 1 and 2 demonstrate the correlation between rectal and axillary, and rectal and average tympanic temperatures, showing a wider degree of scatter of the variables in the former than in the latter.

The sensitivity of tympanic measurements in detecting rectal temperatures $\geq 38.0^{\circ}\text{C}$ ¹⁶ was 91.5%, while that of axillary measurements was 54%. On the other hand, the sensitivity of axillary measurements in detecting fever was only 32.4% for low-grade fever with rectal temperatures of 38.0–38.9°C, compared with that of tympanic measurements, which was

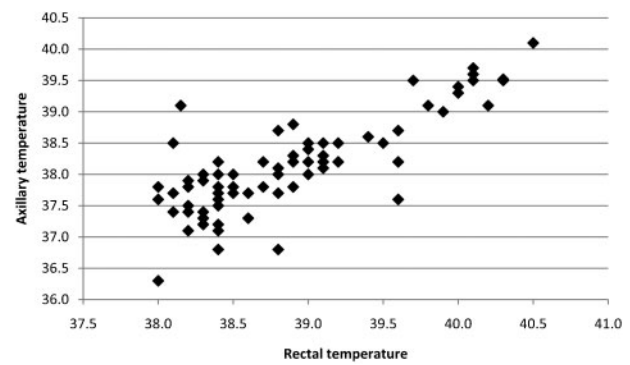


Figure 2 Correlation scattergram of paired rectal and axillary temperatures (°C)

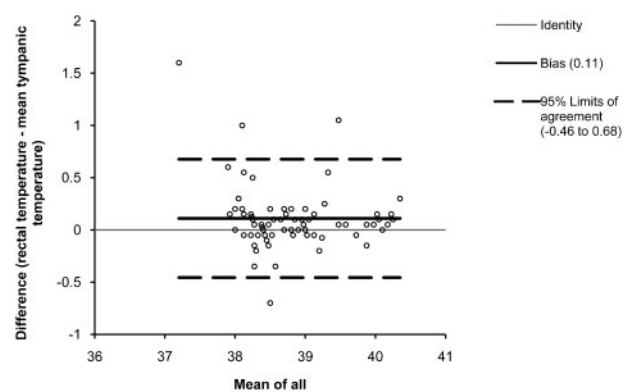


Figure 3 Bland–Altman plot of rectal and mean tympanic temperatures

87.0%. However, the sensitivity of axillary temperatures in detecting fevers with rectal temperatures of $>38.9^{\circ}\text{C}$ was about 100%. Using generally agreed cut-offs for axillary ($\geq 37.5^{\circ}\text{C}$) and tympanically determined fever ($\geq 37.8^{\circ}\text{C}$),^{6,12} the sensitivity of these measurements in detecting rectally determined fever (rectal temperature $\geq 38.0^{\circ}\text{C}$)¹⁶ was 96.2% for tympanic measurements and 77.8% for axillary measurements.

The Bland–Altman plot (Fig. 3) comparing rectal and tympanic temperatures shows a high degree of agreement with a low bias of 0.11 and a trend of reducing differences with higher mean temperatures (95% CI -0.46–0.68). Figure 4 shows a Bland–Altman plot comparing rectal and axillary temperatures with

Table 1 Summary of temperature measurements from all sites

Statistical parameter	Rectal (°C)	Left tympanic (°C)	Right tympanic (°C)	Mean tympanic (°C)	Axillary (°C)
Mean (SD)	38.8 (0.6)	38.7 (0.7)	38.7 (0.7)	38.7 (0.7)	38.1 (0.7)
Median	38.8	38.7	38.6	38.6	38.0
Mode	38.4	38.3	38.4	38.4	37.8
Minimum	38.0	36.3	36.5	36.4	36.3
Maximum	40.5	40.2	40.2	40.2	40.1

Table 2 Comparison of paired temperature measurements

Statistical parameter	Rectal (°C)	Mean tympanic (°C)	Axillary (°C)	Correlation (r)	t	P -value
Mean (SD) (rectal vs mean tympanic)	38.8 (0.6)	38.7 (0.7)	–	0.91	1.48	0.14
Mean (SD) (rectal vs axillary)	38.8 (0.6)	–	38.1 (0.7)	0.82	14.25	0.001

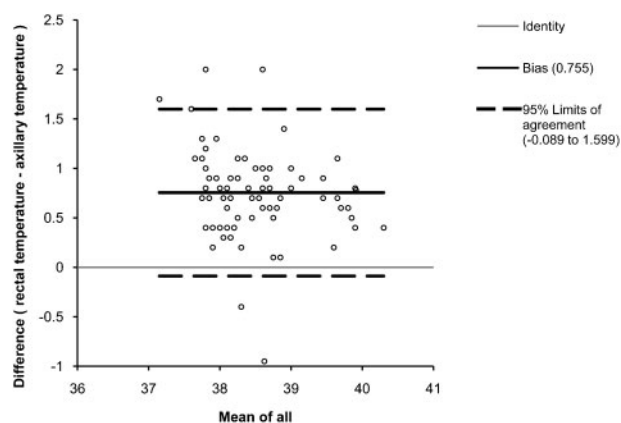


Figure 4 Bland-Altman plot of rectal and axillary temperatures

a high bias of 0.755 and a consistent variability across various temperature cut-offs (95% CI -0.09–1.6).

The derived linear mathematical relationship between rectal and axillary temperatures using linear regression analysis is shown in Figure 5. The derived slope of the graph shown in Figure 5 is 0.71, while the intercept is 11.7. Thus, the mathematical relationship between rectal and axillary temperatures derived from the above is:

$$RT = 11.7 + 0.71 \times AT \text{ [RT, rectal temperature (}^{\circ}\text{C);}$$

$$AT, \text{ axillary temperature (}^{\circ}\text{C)]}$$

On the other hand, for the mathematical relationship between rectal and tympanic temperatures, the derived slope of the line in Figure 6 is 0.85 and the intercept is 6.03. Thus, the mathematical relationship between rectal and tympanic temperatures derived from the above is:

$$RT = 6.03 + 0.85 \times MTT \text{ [RT, rectal temperature (}^{\circ}\text{C);}$$

$$MTT, \text{ mean tympanic temperature (}^{\circ}\text{C)]}$$

Discussion

Over the past two decades, tympanic thermometry has been widely accepted by health-care providers. Reports have shown that nurses, parents and even children have

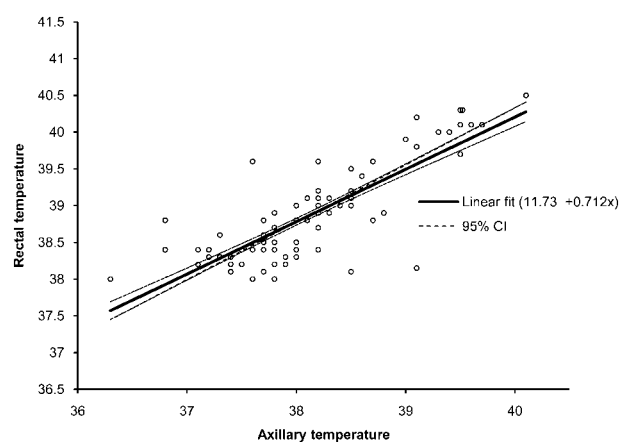


Figure 5 Linear regression analysis scattergram of rectal and axillary temperatures

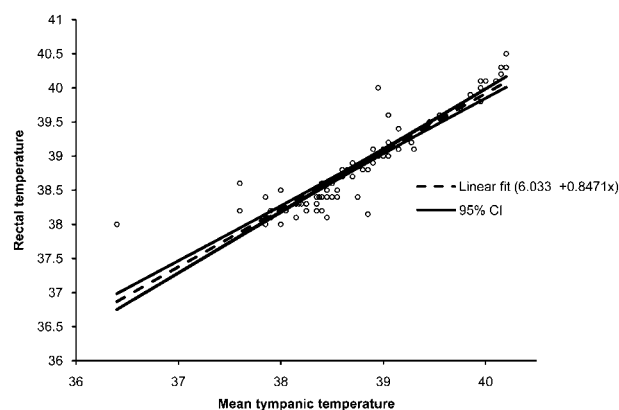


Figure 6 Linear regression analysis scattergram of rectal and mean tympanic temperatures

rated it favourably in terms of rapidity, ease of use, cleanliness, safety and cost-effectiveness.^{18,19} Several reports have highlighted the accuracy of infrared tympanic thermometry compared with traditional techniques for measuring temperature.^{8,20–23} In the present study, there was strong correlation between tympanic temperatures obtained from both ears. This is consistent with earlier reports.^{22,24} Kenney *et al.* studied the reproducibility of tympanic temperature measurements and found a mean (SD) difference of 0.01°C (0.02) that was not statistically significant,²⁴ which is similar to the mean (SD) difference between right and left tympanic readings in this study of 0.02°C (0.11). This suggests that single measurements from either ear can be used in taking measurements rather than an average of both ear recordings. In keeping with previous reports, mean tympanic and rectal temperatures compared favourably.^{10,22,25} On the other hand, axillary temperatures were an inaccurate reflection of fever, similar to other reports.^{20,26,27} Using the recognised cut-off values for axillary and rectal temperatures,¹⁶ 22% of patients who were truly febrile would have been mis-classified as afebrile. This inaccuracy of axillary temperatures is especially pronounced in those with low-grade fever (38.0–38.9°C), in only 32.4% of whom would it be detected. This is slightly higher than the 24% sensitivity recorded by Radhi *et al.*²⁰ for axillary measurements in detecting fever in the same range (38.0–38.9°C). Similarly, in the current study, the sensitivity of tympanic measurements (87%) for low-grade fever was slightly higher than that reported by Radhi *et al.* (76%).²⁰ The importance of accurate axillary temperature measurement can hardly be overstressed in tropical regions where febrile illnesses such as malaria, with its potential for severe complications, are likely to present early with fever as the only symptom and/or physical sign; the consequences of not detecting fever in this group could be catastrophic. There was a greater degree of agreement over a wide range of values between rectal and tympanic vs rectal and axillary measurements. This is further supported

by the wider degree of scatter of axillary measurements, similar to reports by Romano²⁵ and Nimah.²² Based on the known variations, a number of authors have questioned direct comparison between temperature measurements at different sites. However, using the cut-offs for axillary and tympanic temperatures, the current study demonstrated a much lower sensitivity of axillary measurements (78%) than of tympanic (92%).

The mathematical formulae demonstrated a linear relationship between these measurements. Several attempts to define a consistent mathematical relationship between axillary and rectal temperatures have met with limited success, probably as a result of the demonstrated inaccuracies and methodological concerns. In the past, it was suggested that 0.5°C be subtracted from rectal measurements to arrive at axillary measurements. However, this study and several others show this to be an over-simplification.³⁰ A study of the relationship between rectal and tympanic readings found an intercept of 7.54 and slope of 0.8,³¹ similar to the intercept of 6.03 and slope of 0.85 demonstrated in this study.

There is a need for further validation of the derived formulae to determine its degree of accuracy in predicting rectal temperatures when they cannot be conveniently performed.

Tympanic temperature, measured by rectal thermometry, is a sensitive, reliable and accurate reflection of core body temperature. Axillary temperatures are not reliable in reflecting core body temperature and have poor agreement with rectal temperature measured at the same time. In children <5 years of age, the mathematical formula [rectal temperature (°C)=6.03+0.85 × tympanic temperature (°C)] can be helpful in accurately predicting rectal temperature. The mathematical formula [rectal temperature (°C)=11.7+0.71 × axillary temperature (°C)] can also be used to predict rectal temperature from measured axillary temperature in children <5 years of age.

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