Comparison of Rectal, Axillary, Aural and non-contact thermometers in Febrile children

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Abstract
Introduction: *Highest incidence of febrile illnesses occur in infancy and early childhood and it is essential to determine body temperature accurately, allowing rapid identification of potentially life threatening conditions. Rectal temperature is considered as 'Gold standard' but it is inconvenient. This study was designed to assess and compare the performance of three commercially available thermometers, a digital thermometer for axillary and rectal temperature measurement, a non-contact infrared thermometer for forehead temperature measurement and an infrared tympanic membrane thermometer.*

Methods and Materials: *It was a descriptive study done in febrile children aged 3 months to 5 years, from September 2016 to February 2017 in Department of Paediatrics, Government Medical College and Hospital, Vellore, Tamil Nadu.*

Results: *Mean rectal temperature was $38.96^oC \pm 0.62^oC$. Mean tympanic membrane temperature was $38.80^oC \pm 0.64^oC$. Mean axillary temperature was $38.04oC \pm 0.62oC$. Mean forehead temperature was $38.38^oC \pm 0.65^oC$. The co-efficient of correlation between mean rectal and tympanic membrane temperature was 0.958 and between mean rectal and axillary temperature was 0.907. The co-efficient of correlation between mean rectal and forehead temperature was 0.940.*

Conclusion: *Children experienced more discomfort during rectal thermometry than with others. Amongst the three method, tympanic membrane temperature closely correlated and reflected the rectal temperature.*

Keywords: *Tympanic membrane temperature; rectal temperature; axillary temperature, non-contact thermometer.*

Introduction

Febrile illnesses have their highest incidence in infancy and early childhood, and fever is the leading symptom bringing children to the pediatrician. Fever may be the only objective indication of serious bacterial infection such as sepsis etc., which includes meningitis [1].

Accurate determination of body temperature is essential, allowing rapid identification of potentially life threatening conditions. The

accepted method for accurate determination of body temperature in non-neonatal ambulatory children is by inserting a thermometer into the rectum to obtain a rectal temperature which is often considered the "gold standard" for clinical use. However, rectal temperature measurement is inconvenient, invasive, time consuming, potentially painful and not possible in children with diarrhoeal diseases [2].

The tympanic membrane shares the same vascular supply that perfuses the hypothalamus and is an excellent, readily accessible site for core temperature measurement. Infrared thermometers that enable temperature to be measured at the external ear canal have become available in the past 15 years and have been introduced into wide spread clinical use. Newer infrared thermometers have come which has enabled us to measure temperature by non-contact method [3].

This study was designed to assess and compare the performance of three commercially available thermometers, a digital thermometer for axillary and rectal temperature measurement, a non-contact infrared thermometer for forehead temperature measurement and the other an infrared tympanic membrane thermometer.

Materials and Methods

Five hundred children with fever in the age group between 3 months to 5 years, who attended the Department of Pediatrics, Government Vellore Medical College, Vellore, were included in the study. They were randomized. Children with suppurative Otitis media, otitis externa, large amount of wax, anal fissure and those with diarrhoeal diseases were excluded from the study. A cutoff of 38˚C was kept to define a febrile patient. Informed written consent was obtained from the caretakers / parents of the children.

Rectal temperature was obtained by using a digital electronic thermometer. Axillary and Rectal temperature measurements were taken using OMRON MC-246 digital thermometer. A probe cap was initially mounted over the tip and water soluble lubricant jelly was applied over the probe.

They were positioned properly (child in left lateral position, in supine position) and the buttocks were separated and thermometer was inserted without force to a distance of 1 – 1.5 cm into the rectum. When the reading was ready, the thermometer would emit a [beep-beep-beep] sound three times. Ear temperature was measured by using Chicco infrared ear thermometer. A probe cap was housed on the thermometer case as instructed in operation manual. The center of the probe cap was aligned with the center of the probe. Ear was pulled back slightly to straighten the ear canal (for children under 1 year – pinna was gently pulled backwards and for children over 1 years of age pinna was gently pulled upwards and backwards). "Scan" button on the right side of the thermometer was pressed and the beep signal was taken as end point and the reading was noted. The same procedure was repeated in the other ear. Separate probe caps were used for each child.

Forehead temperature was measured by using Equinox Touchfree infrared thermometer. The forehead was made free of sweat and hairs if any were moved aside. Power button was pressed to turn on the thermometer. The scan button was pressed and held down and the thermometer was gently moved towards the temporal area at distance of about 4 – 6 cm. The scan button would then be released and a short beep was heard which indicated end of measurement. The temperature displayed instantly was measured. Two readings were taken in time gap of 30 seconds.

The instruments were pre-calibrated. Attempts were made to take all readings in patients within ten minutes and in following order: forehead temperature → ear temperature → axillary temperature → rectal temperature.

After measurements, parental and patient preference was assessed for all the techniques. FLACC pain scale was used to assess the level of discomfort experienced by children during each procedure. Relevant investigation for the diagnosis was done as and when and appropriate treatment was initiated.

The data were analyzed using SPSS ver. 18.0 and following statistical methods were applied.

- Descriptive statistic which includes mean, standard deviation and range to know the nature of sample, age and group wise.
- Product moment correlation to find out the relationship between temperature recorded among different age groups.
- Graphical representation of two temperature considering x and y axis.

Results

A total of 500 children admitted with fever during the period September 2016 to February 2017 were enrolled in the study.

Table 1. Descriptive Statistics of the Sample Selected

Gender	No. of Cases	Mean (Months)	Standard Deviation (Months)
Male	296	23.11	15.583
Female	204	24.44	14.818

't' = 0.955 & (Df = 498.340 > 0.005) Not significant

The mean age of children is found to be around 23 – 24 months i.e., around 2 years. When 't' test is applied to these values, a non-significant difference existed between males and females.

Table 2. Descriptive Statistics for Axillary and Rectal Temperature Measurement

Temperature (^{o}C)	N	Minimum ^{o}C	Maximum ^{o}C	Mean ^{o}C	Standard Deviation ^{o}C
Rectal Temperature	500	38	40.9	38.96	0.62
Axillary Temperature	500	36.4	39.6	38.04	0.62

Table 3. Descriptive Statistics for Tympanic Membrane Temperature

Ear Temperature (^{o}C)		N	Minimum ^{o}C	Maximum ^{o}C	Mean ^{o}C	Standard Deviation ^{o}C
Left Ear	Reading 1	500	36.40	40.80	38.8024	.64204
	Reading 2	500	36.40	40.80	38.8037	.64867
Right Ear	Reading 1	500	36.50	40.80	38.8042	.64690
	Reading 2	500	36.50	40.80	38.8050	.64550
Average		500	36.45	40.80	38.8038	.64371

The mean values of the readings taken in both ears is nearly equal and the difference exists in the 2nd decimal point. The intra patient correlation between the two readings on right ear (r = 0.993) and that between the two readings on the left side (r = 0.994) were highly significant (p<0.0001) indicating that there was high reliability in the measurement of first and second readings of the temperature of respective ears.

Table 4. Descriptive Statistics for tympanic membrane temperature for the entire sample

Ear Temperature (^{o}C)	N	Minimum (^{o}C)	Maximum (^{o}C)	Mean (^{o}C)	Std. Deviation (^{o}C)
Right Ear	500	36.400	40.800	38.803	0.644
Left Ear	500	36.500	40.800	38.805	0.645
Both Ear	500	36.45	40.80	38.8038	0.643

Comparatively the mean temperature from both ears is nearly the same. The difference exists in the third decimal and it is totally negligible. The mean temperature difference between the two ears is 0.002 ^{o}C. The intra patient correlation between the readings of right and left ears was highly significant (r=0.994, p<0.0001).

Table 5. Descriptive Statistics for Forehead Temperature

Forehead Temperature (°C)	N	Minimum °C	Maximum °C	Mean °C	Standard Deviation°C
Reading 1	500	37.00	40.60	38.3798	.64919
Reading 2	500	37.00	40.60	38.3816	.65065
Average	500	37.00	40.60	38.3807	.64950

The mean values of the readings taken in forehead is nearly the same. The paired 't' test revealed a correlation value of 0.997 and p value of 0.397 (P>0.05) and no significant difference exists between the two readings.

Table 6. Temperature difference between the mean of rectal, axillary, ear and forehead temperature.

Mean Temperature Difference (°C)	Minimum (°C)	Maximum (°C)	Mean (°C)	Std.Deviation (°C)
Rectal & Ear	1.55	0.1	0.156	0.21
Rectal & Forehead	1	0.3	0.579	0.26
Rectal & Axillary	2.4	1.3	0.919	0.002

The difference between mean rectal temperature and that of ear, forehead and axillary temperature are 0.156°C, 0.579°C and 0.919°C respectively. All the three temperature correlated significantly with the rectal temperature. The 'r' value by Pearson Correlation matrix between Rectal & ear temperature is 0.958 and p is <0.0001 which is significant. Similar comparison between rectal temperature and forehead temperature reveals 'r' value of 0.940 and $p < 0.0001$ and it is highly significant. Comparison of rectal temperature with axillary temperature reveals a 'r' value of 0.907 and $p < 0.0001$.

All the three readings have high correlation with the rectal temperature. The tympanic membrane temperature has the highest correlation among the three with the rectal temperature which is shown by the least mean temperature difference and higher correlation value.
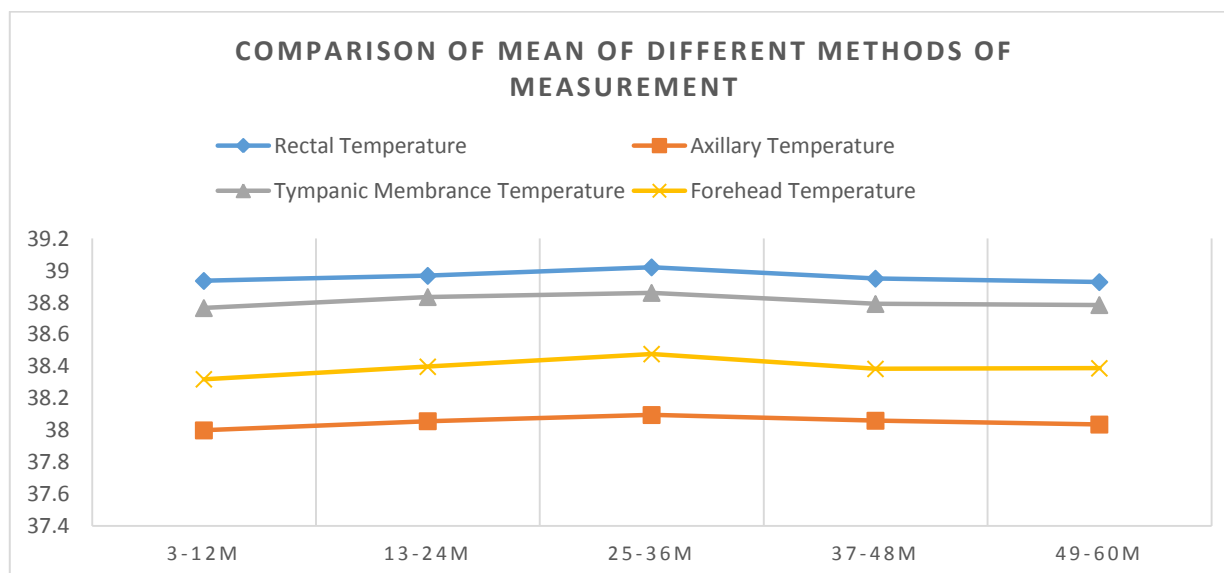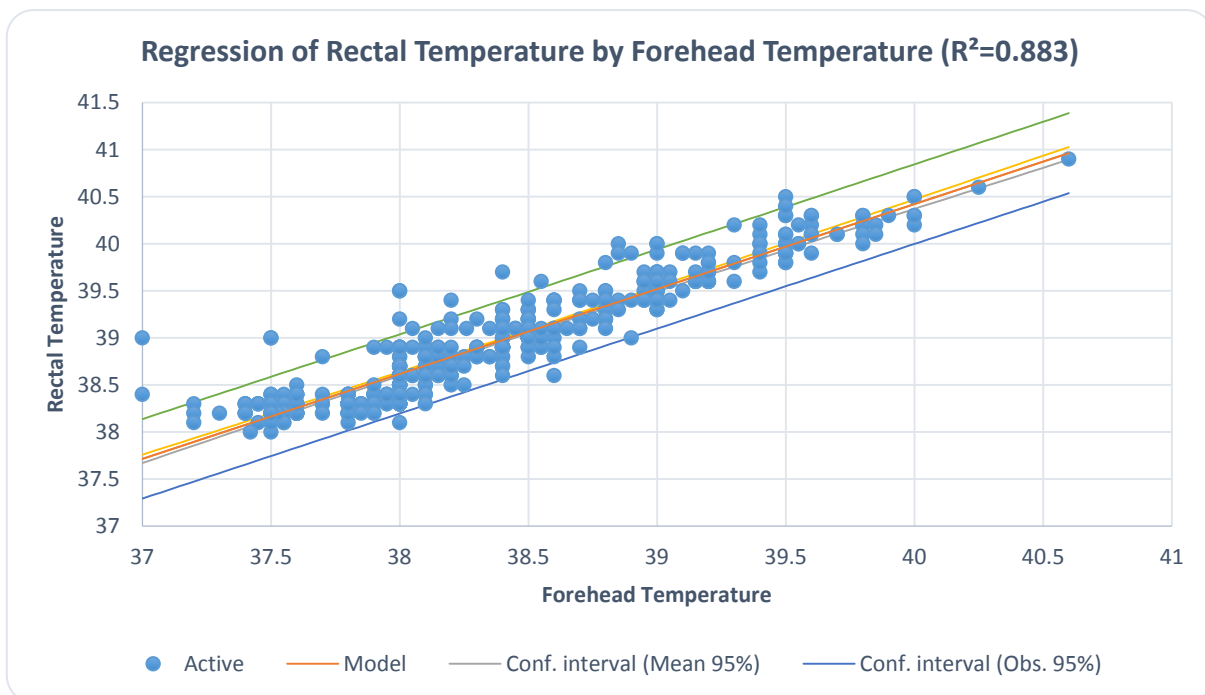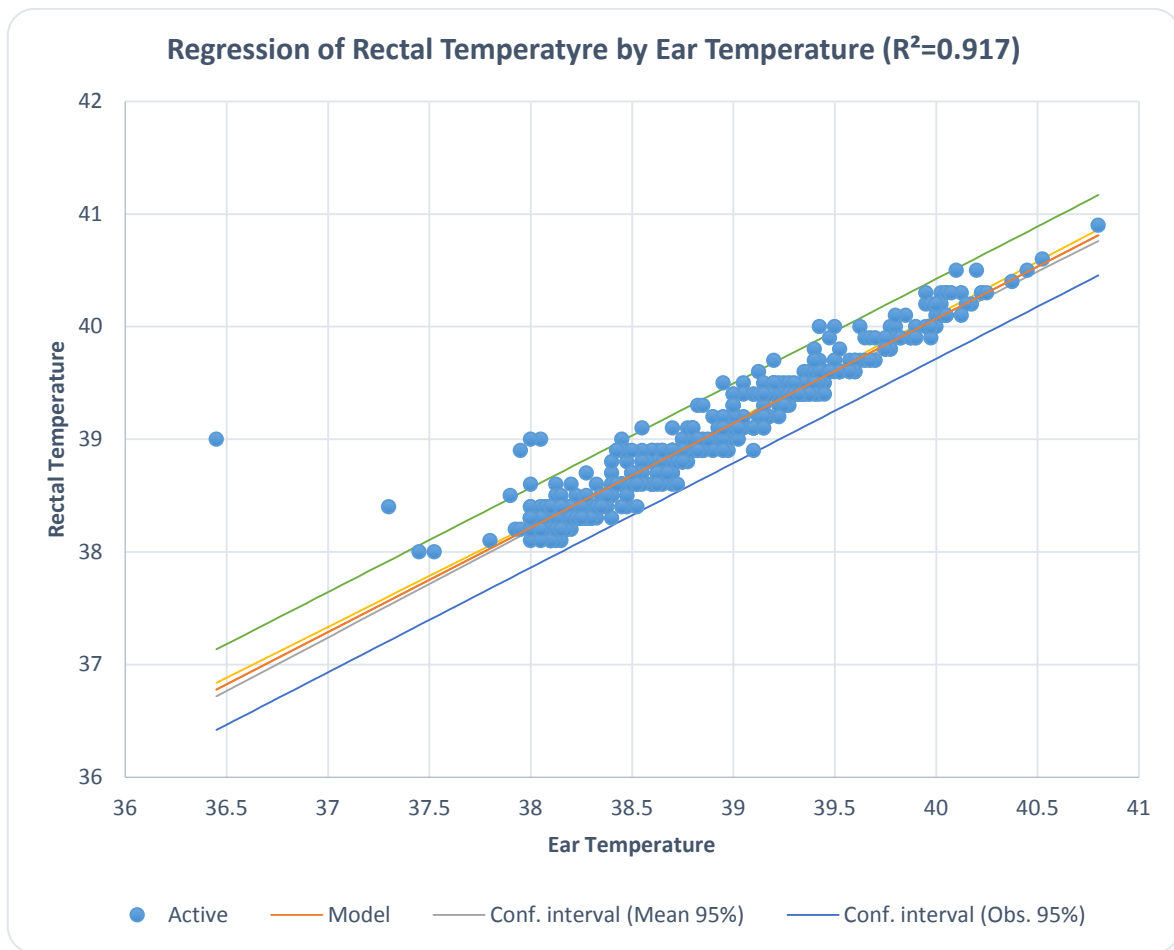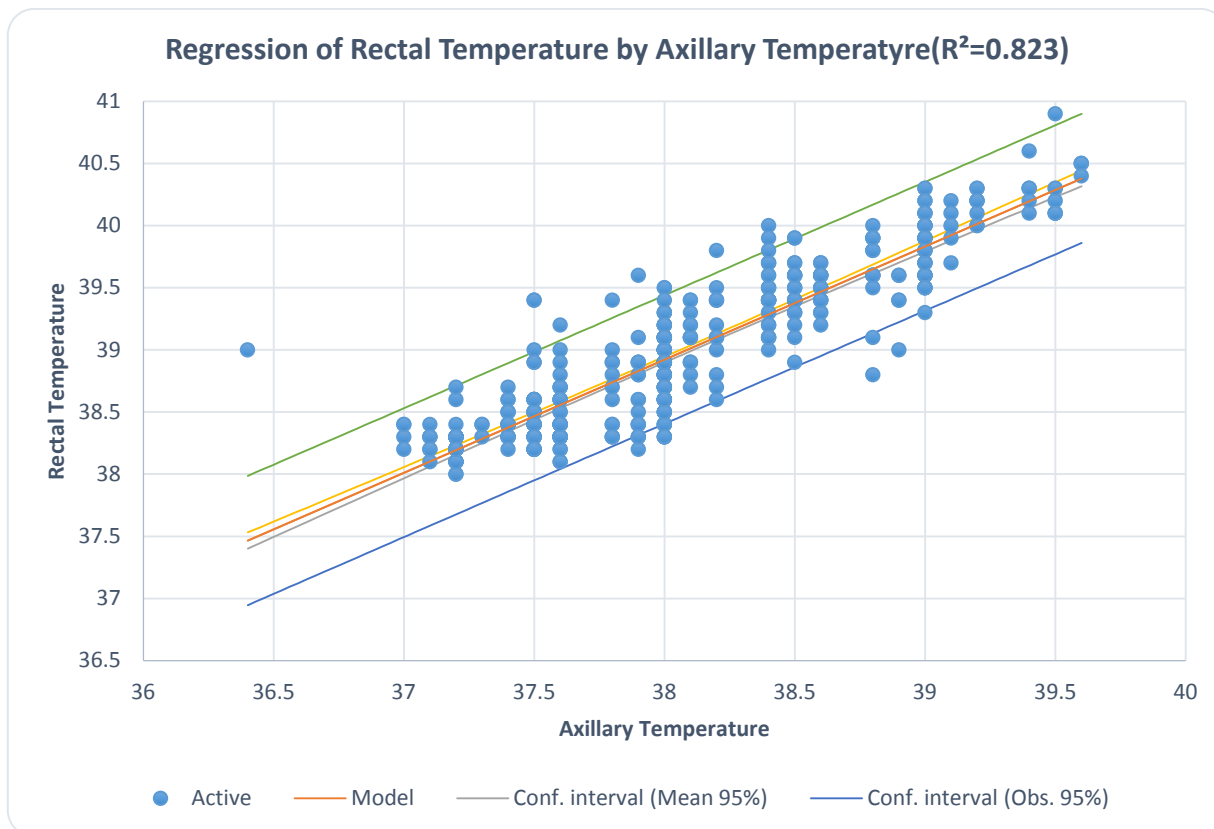

Comparison by Linear Regression

Linear regression was performed between mean tympanic membrane temperature readings and rectal temperature readings with rectal temperature as dependent variable and tympanic membrane temperature as independent variable. A straight line was obtained which signifies a direct correlation between the two. Similar linear regression was performed with rectal and axillary temperature and rectal temperature with forehead temperature. Of the three, tympanic membrane temperature has R^2 value of 0.917 and signifies

that tympanic membrane temperature closely correlates with that of Rectal temperature than the other methods of measurement.

Regression of Rectal Temperatyre by Ear Temperature (R²=0.917)

Regression of Rectal Temperature by Forehead Temperature (R²=0.883)

Regression of Rectal Temperature by Axillary Temperatyre(R²=0.823)

Table 7. Comparison of Pain scale by FLACC score:

FLACC Score	Nos	Min	Max	Mean	S.D
Axillary	500	3	7	4.65	.743
Rectal	500	8	10	8.98	.551
Aural	500	2	6	3.90	.715
Forehead	500	1	5	2.92	.488

It is evident that measurement of temperature by rectal thermometer was more painful when compared to that of other methods and Forehead thermometer which has mean value of 2.92 is the least painful procedure.

Discussion

The era of infrared thermometers has begun and research is needed to establish its efficacy.

Table 8. Comparison of Number of Cases, Age Range, Gender and Mean age with other Studies

	Arvind Sehgal et al(4)., 2002	Bernardo et al(5)., 1996	Jean-Mary MB et al(6)., 2002	Chathurvedi et al(7)., 2004	Abdulkadir MB et al(8)., 2013	Thomas E Terndrup et al(2)., 1991	El Radhi AS et al(9)., 2006	Present Study
No of cases	60	38	198	100	400	303	106	500
Age Range in Years	0.6 – 9	1-14	3m – 36m	<1 yr	0-5yrs	<16	<1 yr	3mo – 5 yrs.
Gender (M/F)	31/29	-		55/45	-	176/127	-	296/204
Mean Age in Years	4.47±2.5	6.9	1.3yrs	0.36	-	1.6±0.9	-	1.97±1.27

Table 9. Comparison of findings of our study with previous studies

Sl. No.	Comparison of Mean Temperature Difference between Ear and Rectal Readings with other studies		Comparison of Mean Temperature Difference between Axillary and Rectal Readings with other studies		Comparison of Mean Temperature Difference between Forehead and Rectal Readings with other studies	
	Studies	Mean Temperature Difference (in ^{o}C)	Studies	Mean Temperature Difference (in ^{o}C)	Studies	Mean Temperature Difference (in ^{o}C)
1.	Present Study	0.196	Present Study	0.919	Present Study	0.579
2.	Thomas E Terndrup et al(2), 1991	0.00	Shann F et at(10)., 1996	1.04	Kistenmaker JA et al(11)., 2006	0.5
3.	Arvind Sehgal et al(4)., 2002	0.01	Robinson JL et al(12)., 1998	1.3		
4.	Hooker et al(13)., 1996	0.29	Bliss-Holtz et al(14)., 1989	0.8		
5.	Stewart et al(15)., 1992	0.20	Ogren JM et al(16)., 1990	1.81		
6.	Wilshaw et al(17)., 1999	0.20	El-Radhi AS et al(9)., 2006	1.58		
7.	Hoffman et al(18)., 1999	0.18	Chaturvedi et al(7)., 2004	0.8		
8.	Nypaver et al., 1991	0.35	Musumba CO et al(19)., 2005	0.74		

Table 10. Comparison of Correlation of Co-efficient of our study with previous studies

Correlation between Tympanic membrane and Rectal Temperature				
	Arvind Sehgal et al(4), 2002	Terndrup TE et al(2)., 1991	Abdulkadir MB et al(8)., 2013	Present Study
Co-efficient of Correlation	0.994	0.90	0.91	0.958
Correlation between Axillary and Rectal Temperature				
	Edelu BO et al(20)., 2011	Chaturvedi et al(7)., 2004	Present Study	
Co-efficient of Correlation	0.94	0.83	0.907	
Correlation between Forehead and Rectal Temperature				
	Kistenmaker et al(11)., 2006	Present Study		
Co-efficient of Correlation	0.89	0.94		

Co-efficient of correlation between tympanic and rectal temperature in the present study was 0.958 and it correlated well with the recent study conducted by Abdulkadir et al in 2013 in Nigeria and were highly significant. Arvind Sehgal et al., and Terndrup TE et al., also found excellent correlation ($r = 0.994$ and $r = 0.90$ respectively) between the two readings. From the scatter plot, it was observed that a perfect relation existed between the two readings($r = 0.917$) which implies that ear temperature can be used successfully to predict the rectal temperature

Co-efficient of correlation between axillary and rectal temperature in the present study was 0.907 and it closely correlated with the study conducted by study conducted by Chaturvedi et al., in 2004. Co-efficient of correlation between forehead and rectal temperature in the present study was 0.94 as compared to 0.89 in the study conducted by Kistenmaker et al., in 2006.

Table 10. Comparison of Correlation co-efficient in the present study:-

Variables	Axillary Temperature	Ear Temperature	Forehead Temperature
Rectal Temperature	0.907	0.958	0.940

From the above table, it is evident that among the three methods, ear temperature with correlation co-efficient of 0.958 correlates better with the rectal temperature than the others (Axillary – 0.907 and Forehead temperature – 0.947).

Conclusion

Fever is an important indicator of infection in children. The height of the fever correlates with the likelihood of serious bacterial infection and occult bacteremia. With the technology of today, patterns of fever are seldom used to narrow a differential diagnosis. It is important to be able to detect and document fever accurately.

Ear and forehead are potentially convenient sites for paediatric temperature measurement and in this study it has been shown that ear temperature correlates well with "core" body temperature than the axillary or forehead method. It is also well accepted by children and parents.

Compared to oral, axillary and rectal thermometry, ear thermometry has advantages, which include ease of use, rapidity of results, safety, non-invasiveness, patient and health care provider convenience, lack of influence by factors known to spuriously affect oral temperature (tachypnea, recent oral intake, crying etc.) and reliability over a wide range of temperatures.

Rectal thermometry, along with the risk of perforation, has also been shown to lag behind in a dynamic situation where temperature is changing rapidly. It is also not possible to use in case of co-existing diarrheal diseases. Temperature recording is particularly upsetting for the younger child and it is time to consider whether tympanic thermometry can take over from traditional methods of temperature measurement.

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