Comparing the Accuracy of Temperature Measurement between Infrared Forehead Thermometer and Tympanic Thermometer

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Abstract

Background: Body temperature can be measured using an infrared forehead thermometer and tympanic thermometer. **Purpose:** To compare the accuracy of temperature measured between infrared forehead thermometer and tympanic thermometer. **Method:** A total of 342 university students participated in this research. An cross-sectional study was conducted to measure their body temperature using an infrared forehead thermometer and tympanic thermometer. A data collection form was used to collect the baseline data and the temperature of the participants. A total of 684 measurements were recorded. **Results:** The findings from Bland-Altman plots indicate that the body temperature measured with a forehead thermometer and tympanic thermometer at the same room temperature revealed no significant difference. The plot also indicates 95% limits of agreement between the temperature of the forehead and tympanic showed the upper limit of 0.46 and lower limit of -0.45, and the mean bias of 0.0041. Additionally, the results of one-sample t test (p= 0.744) reinforced a concordance between two body temperature measurement methods. **Conclusion:** The study supports the conformity of two measurement values of the infrared and tympanic thermometer and attests infrared forehead thermometer is as reliable and accurate as tympanic thermometer. Hence, infrared forehead thermometer can be used in clinical and basic practice, especially in the emergency setting, where ease of use and speed of obtaining the temperature reading are important.

Keywords: Fever, Thermometer, Tympanic Thermometer, Infrared Forehead Thermometer, Temperature.

1. Introduction

There are many approaches in measuring body temperature including using oral, axillary, rectal, tympanic, skin and internal site. Each approach required different types of technique and thermometer in measuring the temperature (Steven & Stacey, 2021; Susheera et al., 2021). In clinical practice, measuring body temperature has been recognized as one of the five vital signs in patient observation and monitoring.

Tympanic thermometer can be used in hospital settings especially in emergency department since it is easy and quick to use (Gasim et al., 2013), while infrared forehead thermometers can be used to measure temperature rapidly and non-invasively. The forehead site is the most suitable to take temperature via skin

because it supplied by the temporal artery, which receives high blood flow from the carotid artery (Aragón-Vargas, 2020). On the other hand, the tympanic membrane shares the same vascular artery that perfuses the hypothalamus, thus measurement of tympanic membrane temperature reflects core temperature (Jevon & Joshi, 2020). Since both types of thermometers have advantages for temperature monitoring during this COVID-19 outbreak as they are able to provide the readings within seconds (Bharti et al., 2017), thus, are widely used for temperature screening and rapid triaging (Chen et al., 2020). During the acute phase of COVID-19 crisis, body temperature is an important measurement for clinical decision-making in management of patients with COVID-19, so this study is worth investigation as it helps to identify the best thermometer to use during this outbreak. In addition, to compare the accuracy of temperature readings between tympanic and forehead thermometers, and looking forward to mitigate the occurrence of false-negative cases in the university which may result in potential future infection clusters which pose more risks to university students who live in campus.

Methods

This study was conducted at AIMST University Malaysia to compare the variation in temperature measurements using infrared forehead thermometer and tympanic thermometer. A cross-sectional study was employed targeting at university students at AIMST University students to measure their body temperature using both types of thermometers. A total of 342 university students were randomly selected from population of 3,100 and enrolled in the study. Sample size calculation was based on Krejcie and Morgan (1970) sample size determination table. Informed consent was obtained from all students participated in the study. The participants who consented were briefed about the procedure by research team before the temperature were taken. The participants' demographic information was also captured before the procedure of temperature measurement. The procedure took about 5 minutes to complete two readings measured from each student using tympanic thermometer followed by infrared forehead thermometer, the temperature measurement for both sites was based on guidelines as stipulated for respective device. After the measurements were taken, subsequently the readings were immediately documented in temperature recording form together with the time of procedure performed (Figure 1). The data collection was held at University cafeteria zone who offer a more spacious area for research team to implement the research work on temperature measurements. All the recruited students were contacted to present themselves at the venue to have their body temperature measured. Those students who were not available due to various reasons were excluded. University staffs were also excluded in this study. Data collection were conducted from 7 January 2022 to 13 January 2022 for a period of one week.

Two types of thermometers were used in this study, the tympanic thermometer model Omron-TH-839S for body temperature measurement at tympanic site while the infrared forehead model Omron MC-720 was utilized for measurement at forehead. Tympanic thermometer is an electronic

thermometer that determines the temperature electronically by measuring it from the tympanic membrane of the ear (Ajcevic et al., 2022) whereas infrared forehead thermometer is a handheld thermometer that is placed on, passes over, or pointed at the forehead to measure a person's body temperature from a branch of superficial temporal artery by pointing an infrared scanner directly at the forehead or lightly passing the scanner across the skin of the forehead (Sampath et al, 2022). The study was approved by AIMST University Human & Animal Ethics Committee with reference no: AUHEC/FAHP/2022/01 dated 30 September 2021.

The data collected were analyze with SPSS (Statistical Package for Social Sciences) version 25 (SPSS Inc., Chicago, IL. USA) software.

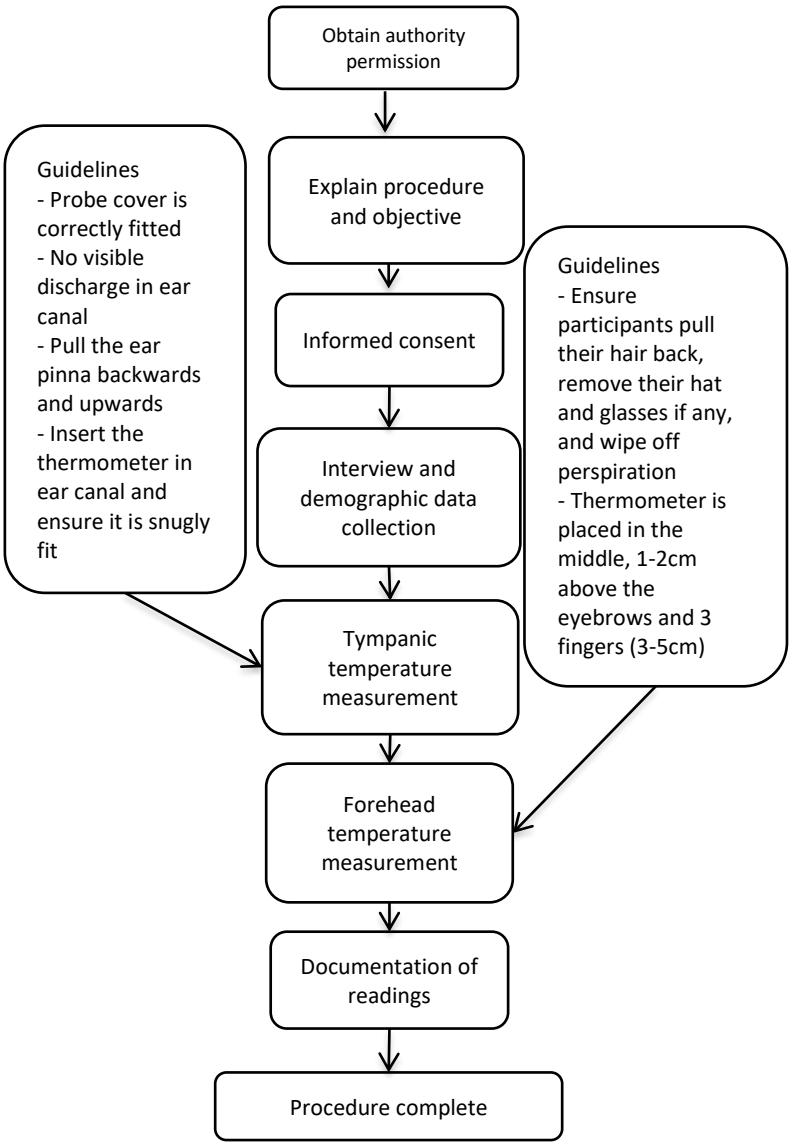

Figure 1: Flow chart of data collection procedure

Results

All 342 selected participants had attended the temperature measurement session. Out of all participated, 269 (78.7%) was female and 73 (21.3%) was male. For ethnicity, there were 161 (47.1%) Indian, 138 (40.4%) Chinese, 34 (9.9%) Malay and remaining 9 (2.6%) was other races. The participants were aged between 18 to 33 years old. Majority of them, 254 (74.2%) of participants were aged between 21 to 25, 76 (22.2%) participants below 20 years old, 9 (2.7%) participants aged 26 to 30 years old, while 3 (0.9%) participants aged between 31-33 years old. In terms of faculty, there were 122 (35.7%) participants from Faculty of Allied Health Professions, 121 (35.4%) participants from Faculty of Medicine, 9 (2.6%) participants from Faculty of Pharmacy, 14 (4.1%) from Faculty of Dentistry, 51 (14.9%) participants from Faculty of Biotechnology, 8 (2.3%) participants from Faculty of Engineering, and lastly, 17 (5%) participants from Faculty of Business. Out of all participants, 119 (34.8%) was year 3, followed by 108 (31.6%) from year 2, 63 (18.4%) year 1, 15 (4.4%) year 4 and lastly 37 (10.8%) were in their fifth year of study (Table 1).

Table 1: Demographic characteristics of samples

	Frequency	Percentage (%)
Gender		
Male	73	21.3
Female	269	78.7
Race		
Chinese	138	40.4
Malay	34	9.9
Indian	161	47.1
Others	9	2.6
Age		
<20	76	22.2
21-25	254	74.2
26-30	9	2.7
31-35	3	0.9
Faculty		
Faculty of Allied Health Professions	122	35.7
Faculty of Medicine	121	35.4
Faculty of Pharmacy	9	2.6
Faculty of Dentistry	14	4.1
Faculty of Biotechnology	51	14.9
Faculty of Engineering	8	2.3
Faculty of Business	17	5.0
Year of Study		

Year 1	63	18.4
Year 2	108	31.6
Year 3	119	34.8
Year 4	15	4.4
Year 5	37	10.8

A total of 684 measurements were performed, in which 342 measurements were taken with tympanic thermometer and another 364 measurements were with infrared forehead thermometer. To check for agreement between two methods of temperature measurements, one-sample T test was used to assess the agreement between both measurement methods. The results demonstrated mean temperature taken by infrared forehead and tympanic thermometer was 36.4754℃ and 36.4713℃ respectively. The standard deviation was 0.250 for infrared forehead thermometer while 0.230 for tympanic thermometer. The mean difference between these two thermometers were 0.0409 while 95% confidence interval of the difference showed lower bound of -0.0206 and upper bound of 0.0287. The t-value of the test was 0.327 with degree of freedom of 341. The results showed no significant difference between two methods of temperature measurements ($t(342)=0.327$, $p>0.05$)(Table 2). This clearly depicted that both methods of temperature measurements are in agreement to each other, and it further warrants to construct a Bland-Altman Plot.

Table 2: Results of one-sample t test

	Mean	SD	Mean Difference	95% CI of the Difference		t	df	p
				Lower	Upper			
Infrared Forehead Thermometer	36.4754	0.250	0.0409	-0.0206	0.0287	0.327	341	0.744
Tympanic Thermometer	36.4713	0.230						

Note: SD: Standard deviation; CI: Confidence interval; df: degree of freedom;

To strengthen the agreement findings in temperature measurements using infrared forehead and tympanic thermometers, Bland-Altman plot (Bland and Altman, 1986, 1999; Bland et al., 2007; Altman and Bland,1983) was employed. In the Bland-Altman plot, the x-axis is the mean temperature of the forehead and tympanic, and the y-axis is the bias or difference temperature between the forehead and tympanic. In this plot, a line of mean bias and 95% limits of agreements are presented. The plot of differences (95% limits of agreement) between the temperature of the forehead and tympanic showed the upper limit of 0.46 and lower limit of -0.45, and the mean bias of 0.0041 (Figure 1).

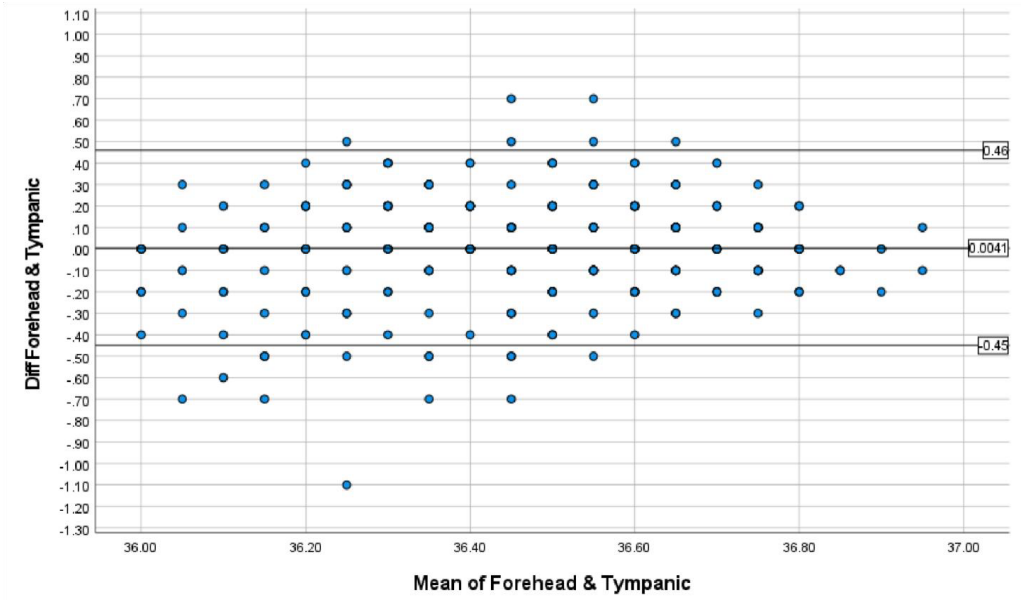

Figure 1: Bland Altman Plot

To further demonstrate the agreement between two methods of temperature measurement, A simple line graph was constructed to confirm the concordance of body temperature measurements between infrared forehead and tympanic thermometer. Both line graphs show positive trend and the values were almost overlapping and close to each other. This depicted a strong correlation between these two temperature measurement methods (Figure 2).

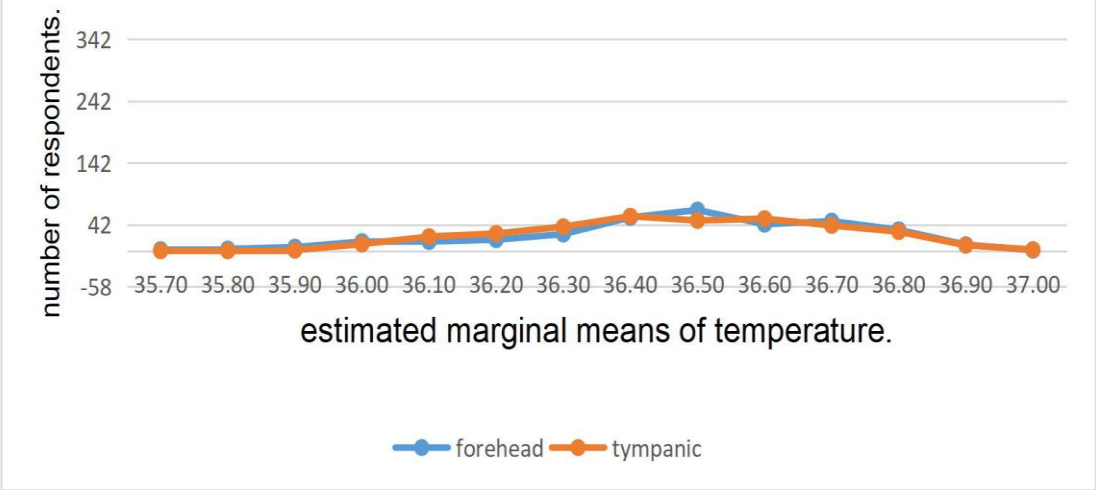

Figure 2: Distribution of temperature measurements between forehead and tympanic thermometer

Discussion

The results from the one sample t-test revealed no statistically significant difference in temperature measurements between the infrared forehead and the tympanic thermometer temperature (p= 0.744). The mean of tympanic temperature is 36.4754ºC while forehead temperature is 36.4713ºC. Thus, the difference of temperature taken by these two thermometers were minimal and less than 0.1ºC. It has shown in several studies (Hymczak et al., 2021; Gasim et al., 2013) that tympanic temperature is quick and simple to use method. Tympanic membrane receives blood from the branches of the internal carotid artery that perfuses hypothalamus and provides good accuracy of readings. Thus, in our study, we had chosen the tympanic temperature as the reference standard for comparison, as recommended by health authorities across the world for best nursing practice (NHS Greater Glasgow & Clyde, 2020).

Besides, this study employed Bland–Altman plot because it is appropriate for method-comparison design in this study. It has been used in several studies to determine the concordance between two methods of temperature measurement (Koh & Yu, 2016; Fong et al., 2021; Sharif et al., 2021; Sweeting et al., 2021). The results of the plot differences (95% limit of agreement) between tympanic temperature and forehead temperature showed upper limit and lower limit and these values are quite close to mean difference temperature of -0.0041. The temperature of the forehead and tympanic showed the upper limit of 0.46 and lower limit of -0.45, and the mean bias of 0.0041. The difference is 0.4559 (0.46-0.0041) for upper limit and 0.4459 (0.45-0.0041) for lower limit (Fig. 2). This finding found no significant differences between forehead temperature and tympanic temperature. The results of the simple line graph showed a positive and strong correlation between temperatures of the forehead and the tympanic thermometer. Hence, the use of infrared forehead thermometer appears to be an acceptable approach for non-invasive temperature measurement for public.

This finding corroborates with a study on 161 nursing students that found non-touch infrared forehead thermometers had significantly different temperature readings compared to digital oral and digital axillary thermometers; but they were similar to the readings of infrared tympanic thermometers (Sweeting et al., 2021). The study revealed infrared non-touch forehead thermometer demonstrated statistically significant higher mean temperatures compared with digital oral thermometer and digital axillary thermometer but not with infrared tympanic. The study concluded that infrared forehead thermometer produced higher temperature readings compared to others peripheral thermometers and reinforced that infrared forehead thermometer should be used with caution. This study revealed the same results with our study because the settings and samplings of the studies are almost the same. The participants of the both studies are healthy adults and no fever detected. Thus, the results supported that infrared forehead thermometer can be used by public but with cautions and should comply with the stipulated guidelines.

Conversely, a study by Fong et al. (2020) found there was significant difference between tympanic temperature and forehead temperature. The forehead temperature is

significantly lower that tympanic temperature because the sweat and hair over the area to be measured have resulted in lower forehead temperature readings. This study was done on febrile participants and the researches recommended to use tympanic thermometer instead of forehead thermometer when screening visitors for fever. On the other hand, study done by Sharif et al. (2021), also demonstrated that the forehead thermometer readings have low agreement with the tympanic measurements. There was bias found with the forehead thermometer having higher readings in the lower temperature ranges. Another study by Zhang et al. (2021) has recommended the use of infrared thermal imaging cameras at the main entrances of hospitals and public places to identify a large number of people for preliminary temperature measurements. While tympanic thermometers can be used in second-line screening in clinic rooms, airplanes, long-distance buses, hotels and classrooms to check the temperature. They also recommended the use of sterilized thermometers for axillary or rectal temperature as the next step in fever clinics, isolation wards, inpatient wards and for re-evaluation of cases of suspected fever (Zhang et al., 2021). These studies have different results compared with our study because fever patients were used in those studies. The plausible reason for less concordance of tympanic and forehead temperature in these studies because of the measurement errors. Thus, it is always appropriate that the standard practice guidelines on thermoregulation management should be observed during temperature monitoring and measurement to prevent bias and measurement errors.

The study was limited to only one university students who study at AIMST University in state of Kedah, Malaysia. Due to the persistent outbreak of COVID-19, the experiment of this study was carried out on students who resided in hostel excluding students who did not attended face-to-face class in the campus. Thus, only 342 participants were taken as a sample size and all the participants were found afebrile. Thus, there was no huge deviation of reading of the temperature and unable to do comparison between the readings for fever cases. Moreover, the equipment including tympanic thermometer and the probe cover provided in the study was limited due to inadequate supply and funding. Thus, we were not able to have extra equipment to involve more participants in the study. To enhance a better finding, a large sample size should be used with well representative samples

Both thermometers able to provide accurate readings if the guidelines are followed when taking the temperature and the thermometers are safe to use by the public. However, tympanic thermometer is still recommended as a gold standard to detect fever in hospital settings. We would also like to recommend the future researchers to work out and conduct an experiment on febrile and afebrile patients. Then, there will be a different in the readings so a comparison can be made Last but not least, future researchers can also conduct the experiment using different types of thermometers particularly the new innovated thermometer such as face recognition thermometer which can be used by the public to detect fever rapidly.

Conclusion

Temperature is a vital sign, so it should be measured as accurately as possible. Health

care staff should be confident that the equipment is reliable. Unfortunately, literature remains inconclusive about which is the best site for clinical measurement or the best type of thermometer to be used in practice. This research is a simple comparison of two thermometers. It was determined that the measurement values of the tympanic membrane and forehead thermometers conformed with each other and the study had demonstrated that the temperature taken by using infrared forehead thermometer and tympanic thermometer are accurate and reliable. The difference readings of the temperature between two thermometers are within the limit of agreement and readings of temperature provided by both thermometers have positive and strong concordance. Therefore, infrared forehead thermometer and tympanic thermometer are suitable to use in detecting fever in during the COVID-19 pandemic.

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