REVISTA DE ENFERMAGEM REFERÊNCIA
homepage: https://rr.esenfc.pt/rr/
ISSNe: 2182.2883

RESEARCH ARTICLE (ORIGINAL)

Child body thermometry: A comparative study of axillary and tympanic thermometry

Medição da temperatura corporal em crianças: Estudo comparativo entre o método de medição axilar e timpânico

Medición de la temperatura corporal en niños: Estudio comparativo entre el método de medición axilar y timpânico

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Received: 15.01.21
Accepted: 07.12.21

Abstract
Background: Body temperature is one of the most evaluated vital signs in pediatric health care for clinical assessment and guidance.
Objectives: To evaluate the agreement between axillary and tympanic thermometry in children aged 6 to 36 months.
Methodology: An observational and descriptive study was carried out in a level II hospital in Portugal. The thermometry protocol followed the guidelines of the Portuguese Directorate-General of Health.
Results: A total of 331 children participated in the study. The difference between tympanic and axillary temperatures ranged from 0.00ºC to 1.40ºC, with a mean of 0.45ºC ± 0.30ºC and a median of 0.50ºC, an almost perfect agreement between both methods. An effect on the temperature value was observed according to the technique used in all variables studied.
Conclusion: There is an almost perfect agreement between these two thermometry methods, not influencing clinical decision-making. Advantages of the tympanic method over the traditional axillary method include easy implementation and feasibility. Therefore, it can be routinely implemented in assessing temperature in children aged 6 to 36 months.

Keywords: body temperature; thermometers; fever, child; pediatrics; nursing

Resumo
Enquadramento: A temperatura corporal é um dos sinais vitais mais avaliados nos cuidados de saúde pediátricos para avaliação e orientação clínica.
Objetivos: Avaliar a concordância entre a medição da temperatura por via axilar e timpânica em crianças dos 6 aos 36 meses.
Metodologia: Estudo observacional e descritivo desenvolvido num hospital de nível II, em Portugal. O protocolo de medição da temperatura seguiu as orientações da Direção-Geral da Saúde.
Resultados: Participaram no estudo 331 crianças. A diferença entre a temperatura timpânica e axilar variou entre os 0,00ºC e os 1,40ºC com uma média de 0,45ºC ± 0,30ºC e uma mediana de 0,50ºC, com uma concordância quase perfeita entre os dois métodos. Observou-se um efeito no valor da temperatura consoante o método utilizado em todas as variáveis estudadas.
Conclusão: Existe uma concordância quase perfeita entre estes dois métodos de medição da temperatura, não influenciando a tomada de decisão clínica. Dado a maior facilidade de implementação e exequibilidade, as vantagens do método de avaliação via timpânica são superiores ao método tradicional via axilar, pelo que poderá ser implementado como rotina na avaliação da temperatura em crianças dos 6 aos 36 meses.

Palavras-chave: temperatura corporal; termómetros; febre; criança; pediatria; enfermagem

Resumen
Marco contextual: La temperatura corporal es una de las constantes vitales más valoradas en los cuidados de salud pediátricos para la evaluación y orientación clínica.
Objetivos: Evaluar la concordancia entre la medición de la temperatura axilar y la timpánica en niños de 6 a 36 meses.
Metodología: Estudio observacional y descriptivo desarrollado en un hospital de nivel II de Portugal. El protocolo de medición de la temperatura siguió las directrices de la Dirección General de Sanidad.
Resultados: Un total de 331 niños participaron en el estudio. La diferencia entre la temperatura timpánica y la axilar varió entre 0,00ºC y 1,40ºC con una media de 0,45ºC ± 0,30ºC y una mediana de 0,50ºC, con una concordancia casi perfecta entre los dos métodos. En todas las variables estudiadas se observó un efecto sobre el valor de la temperatura según el método utilizado.
Conclusión: Existe una concordancia casi perfecta entre estos dos métodos de medición de la temperatura, sin influencia en la toma de decisiones clínicas. Dada la mayor facilidad de aplicación y viabilidad, las ventajas del método de evaluación timpánica son superiores a las del método tradicional a través de la axila, por lo que puede aplicarse de forma rutinaria en la evaluación de la temperatura en niños de 6 a 36 meses.

Palabras clave: temperatura corporal; termómetros; fiebre; niños; pediatría; enfermería

Escola Superior de Enfermagem de Coimbra

How to cite this article: Ferreira, C. A., Pereira, C. O., Santos, D. H., Borges, J. D., & Batalha, L. M. (2022). Child body thermometry: A comparative study of axillary and tympanic thermometry. *Revista de Enfermagem Referência*, *6*(1), e21008. https://doi.org/10.12707/RV21008

Introduction

Temperature, pulse, respiratory rate, and blood pressure are vital signs that indicate the body's ability to control body temperature, maintain blood flow, and oxygenate tissues in the face of environmental changes and physical and/or psychological stressors (National Institute for Health and Care Excellence [NICE], 2019).

Body temperature was first investigated in 1638 by Sanctorius, who understood the pathophysiological reasons for temperature variations and began to use an instrument to check body heat to initiate or not initiate a therapy. In 1851, the researcher Wunderlich achieved an important medical advance by introducing a temperature measuring instrument from which the mercury thermometer originated, using the axillary region to determine this measurement. He set the basal body temperature at 37ºC, varying between 36.2º and 37.5ºC, and defined a temperature value above 37.5ºC as fever (Sund-Levander et al., 2002).

Body temperature determines the survival of the human being so that it should remain within values that sustain life, despite changes in room temperature, energy expenditure, and calory intake. This thermoregulation is regulated in the anterior region of the hypothalamus, where a reference temperature is set, which may be raised by exogenous pyrogens as a systemic defense response of the body (Bastos, 2002). Consequently, the measurement of body temperature is an essential and almost always determined aspect of pediatric healthcare, as it helps guide the child's diagnosis and care (NICE, 2019). Unreliable temperature measurements can lead to misdiagnosis, omission or delay of necessary treatment, inappropriate clinical guidance, or prescription of unnecessary tests (Franconi et al., 2018). For this reason, body temperature measuring devices should be accurate, non-invasive, time--efficient, inexpensive, safe, and preferably independent of the technique used (El-Radhi, 2014).

Currently, various methods and respective devices are available for measuring body temperature. The axillary route is the most popular method, although other methods include tympanic, temporal, oral, rectal, or infrared reading.

Although fever is the most common reason for recurrent emergency department use, with special relevance in pediatric age, few studies focus on the subject. Most address rectal temperature measurement, and few relate tympanic and axillary temperature, and of these, many use the mercury axillary thermometer. The variability between pediatric age groups is also not addressed, as well as the difference between tympanic and axillary temperature in the fever cycle (Abdulkadir & Johnson, 2013; Oguz et al., 2018).

Thus, this study aims to evaluate the agreement between axillary and tympanic temperature measurements in febrile and apyretic children, between age groups (six to 12 months, 12 to 24 months, and 24 to 36 months), between the different phases of the fever cycle (increment, fastigium, and decrement), between children with and without systemic infection, and between the seasons of the year in which the measurement was taken.

Background

Chronobiology is the science that studies biological rhythms, that is, recurrent biological phenomena with a specific periodicity. Chronobiology pioneer Franz Halberg coined the term "circadian" (from the Latin *circa* meaning "around" and *diem* meaning "day") to refer to rhythms that have approximately 24 hours, on which the biological cycle of almost all living beings is based. Commonly known examples include the sleep-wake, rest-activity, light-dark cycle and the body temperature of a mammal (Halberg et al., 1977).

The typical pattern of body temperature in a circadian rhythm is characterized by the body temperature being lowest in the early morning and early morning (between 2 and 3 o'clock) and highest in the late afternoon and early evening (between 4 and 7 o'clock). This difference is noticeable from six months on (0.50ºC) and gets higher from two to six years of age (0.90º - 1.10ºC). Younger children have higher body temperatures and more pronounced diurnal variability than adolescents and adults due to their increased metabolic rate and larger body surface area (Zomorrodi & Attia, 2008).

Fever is an increase in body temperature above the individual's basal temperature, being associated with an increase in the hypothalamic set point and corresponding to the body's physiological response to a specific agent or organic disturbance. Fever is not a disease, but a defense mechanism, stimulating the immune system and hindering the replication of micro-organisms. As a result, there is an increased survival rate and a faster recovery (Broom, 2007; Direção-Geral da Saúde [DGS], 2018). Most children with fever have a benign and self-limited illness, easily tolerating relatively high body temperatures compared to adults (Broom, 2007).

The pathophysiological changes of the acute phase reaction are triggered by cell mediators called cytokines, which act throughout the body, namely in the cells involved in innate and adaptive immunity and at the level of the hypothalamic thermoregulatory center (set-point). In the hypothalamus, the production of prostaglandins (mainly prostaglandin E2) promotes the activation of receptors in the preoptic nucleus, leading to an increase in the hypothalamic set point, thus giving rise to fever (Broom, 2007). Generally, central and peripheral temperatures rise to 3º to 4ºC above the individual's mean basal temperature, without ever exceeding 42.20ºC. The pathophysiological thermal curve of fever evolves in three phases: increase, plateau and decrease. In the increment phase (phase 1), the physiological mechanisms of heat production and conservation are activated through peripheral vasoconstriction (cold sensation) and shivering. The skin may become marbled, or acrocyanosis may occur (fingers and/or lips). Upon reaching fastigium temperature (phase 2), generalized cutaneous vasodilatation occurs, manifested by flushing and warmth sensation, with a consequent reduction in body temperature (phase 3; DGS, 2018).

Fever and hyperthermia are characterized by increased body temperature but with distinct clinical meanings. Fever differs from hyperthermia as it is an autoregulated

process in which there is an increase or decrease in heat without changes in the hypothalamic set point. In hyperthermia, the process is not autoregulated (changes in the hypothalamic set point). It results from body heating by heat acquisition from external sources or, much less frequently, by tumors or diseases such as hyperthyroidism.
Currently, there are several devices for measuring body temperature, such as digital, Galinstan glass, or infrared (remote or contact) thermometers. The most common sites for temperature measurement in the pediatric population are the axilla, rectal mucosa, oral mucosa, and tympanic membrane. Rectal measurement is considered the most accurate method and which best corresponds to core temperature (DGS, 2018). Most studies consider rectal temperature values above 38ºC as fever (Salgado, 2014). However, this measurement method is invasive and culturally poorly accepted in clinical practice. Cases of bowel perforation are described (Abdulkadir & Johnson, 2013). Furthermore, rectal temperature may not reflect changes in core temperature as it depends on the depth of thermometer insertion, anorectal irrigation, and the presence of feces in the rectal ampulla (Abdulkadir & Johnson, 2013).
Axillary measurement is the most commonly used and practical method (DGS, 2018). Also, taking the temperature via the axilla is safe and easily accessible. However, it is not always reliable due to vasoconstriction resulting from an increase in temperature (especially in the increment phase) and possible local sweating. Thus, there is a poor correlation between axillary and core temperature (El-Radhi, 2014). Near the axilla, the trunk temperature is higher than the arm temperature, so the DGS warns that the axilla temperature takes about 5 minutes to stabilize at the time of measurement (DGS, 2018). Some authors consider axillary temperature measurement uncomfortable for the child (Hayward et al., 2020; Bruel et al., 2020).
Ear thermometers are another method of body thermometry that measures the heat released by the tympanic membrane (when the technique is correctly performed) through infrared radiation (García et al., 2004). This easy, fast, and safe method is sensitive to rapid fluctuations in core temperature as the tympanic membrane and the hypothalamus are irrigated by the carotid artery (Gasim et al., 2013). Thus, tympanic measurement seems advantageous in children with fever rather than axillary. In a meta-analysis published in 2015, the authors revealed that the diagnostic accuracy of tympanic thermometry is high and can be used in pediatric age (Zhen et al., 2015). Studies also show that surgical procedures or trauma to the tympanic membrane do not interfere with the temperature values obtained (Gasim et al., 2013), as well as acute nonsuppurative otitis media, tympanic perforation, or child crying (García et al., 2004; Zhen et al., 2015). However, otitis externa, suppurative otitis media, and abundant cerumen may interfere with the results (García et al., 2004). No statistically significant differences were found between temperature values obtained through the right or left tympanic membrane or between multiple measurements or only one measurement (García et al., 2004; Zhen et al., 2015).
Literature shows that it remains unclear for clinical practice which method of body temperature measurement is the most advantageous to children (Franconi et al., 2018; Hayward et al., 2020; Bruel et al., 2020).

Research questions

What is the level of agreement between axillary and tympanic body temperature measurement?
What effects do specific clinical and demographic variables have on the agreement between these two child body temperature measurement methods?

Methodology

An observational and descriptive study was conducted to assess the agreement between two methods of body thermometry (axillary and tympanic) and their effects on some variables that may influence the clinical status of children. The research was developed over two years (April 2016 to April 2018) in the outpatient consultation, emergency department, and inpatient unit of a pediatric service of a level II hospital, in Portugal.
The study's target population included children aged between 6 and 36 months, randomly and consecutively observed in the morning period, between 8 am and 2 pm, in the above-described hospital specialties and whose legal guardians agreed to participate in the research voluntarily. Children with otitis externa, suppurative otitis media, or cerumen obstructing the external ear canal were excluded. Each child corresponded to a single measurement.
This research was approved by the Board of Directors and Ethics Committee of the Hospital (Minute no. 18/02/2020) where the study was carried out and followed the recommendations of the World Medical Association Helsinki Declaration. Participation was preceded by the signing of an informed consent form by the child's legal guardians.
All temperature measurements were performed by nurse specialists in child and pediatric health trained before the study.
The temperature measurement protocol followed the DGS guidelines (2018). The temperature was measured at ºC, and the instruments used were Tro-Digitherm/flex® digital axillary flexible-tip thermometer and Braun-Welch-Allyn® ear thermometer. Both were calibrated according to their operating principles.
The axillary measurement procedure consisted of cleaning the axilla with a dry compress, placing the measurement sensor in the center of the axilla (thermometer disconnected), and keeping the arm firmly against the trunk for 5 minutes, after which the thermometer was turned on, waiting for the beep. For tympanic temperature measurement, a disposable probe tip was placed in the ear canal, tractioning the pinna backward in the posterior direction and pointing the probe towards the opposite temporal region.

Simultaneous temperature measurement by axillary and tympanic routes was performed on each child. The order of measurement by each of these methods was randomized. The child's demographic and clinical characterization included the variables age, gender, season of the year at the time of measurement, tympanic temperature, axillary temperature, fever phase (increment, fastigium, or decrement) in children with fever, and presence or absence of systemic infection.

Axillary temperature ≥ 37.60ºC and tympanic temperature ≥ 37.80ºC were considered fever (DGS, 2018).

The sample size was calculated with the Sample Size Calculator application (Arifin, 2021), with a significance level of 0.05%, a statistical power at 80%, and an expected agreement of 0.85 with a minimum acceptable of 0.80. A total of 318 temperature evaluations were required.

Statistical analysis was performed using IBM SPSS Statistics software, version 24. The normality of the distributions was analyzed by the Kolmogorov-Smirnov test and histogram analysis, with no assumption of normal distribution of the variables. Descriptive analysis of the data was performed, calculating absolute and relative percentage frequencies for categorical variables and mean, standard deviation, median, and minimum and maximum limits for continuous variables. The intraclass correlation coefficient (ICC) at 95%, a two-factor mixed model for single measures with an absolute agreement, was used to evaluate the agreement between the temperature measurement methods. The effect of interaction between variables was analyzed using Wilks' lambda test by the general linear model. The range of agreement (Miot, 2016) is interpreted as follows: 0.0 *(absent)*, < 0.20 (*poor*), < 0.40 (*slight*), <0.60 (*moderate*), < 0.80 (*substantial*), and ≥ 0.80 (*almost perfect*). In all tests, statistically significant differences were considered whenever $p < 0.05$.

Results

A total of 331 children participated in the study, 83 (25.1%) aged less than 12 months, 97 (29.3%) aged between 12 and 24 months, and 151 (45.6%) aged between 24 and 36 months. Gender distribution was almost equal, being 168 (50.8%) males. Temperature was taken throughout the year, with 167 (50.5%) records during the spring and summer months. Most children, 230 (69.5%), were diagnosed with a systemic infection.

Of the measurements taken, 223 (70.4%) of the children had no fever at the time of assessment. In the presence of fever (108 children), 38 (15.2%) children were in the increment phase, 30 (27.8%) in the fastigium phase, and 40 (37.0%) in the decrement phase.

The axillary temperature ranged between 35.40ºC and 39.70ºC, with a mean of 37.05 ± 0.85ºC and a median of 36.80ºC. The tympanic temperature varied between 36.00ºC and 40.30ºC, with an average of 37.50 ± 0.92ºC and a median of 37.30ºC. The difference between tympanic and axillary temperature ranged between 0.00ºC and 1.40ºC, with a mean of 0.45ºC ± 0.30ºC and a median of 0.50ºC.

The agreement observed between axillary and tympanic thermometry was almost perfect with ICC 95% $_{(1,2)}$ of 0.836 (0.016 - 0.949); $p < 0.001$.

The mean difference in temperature measurement between the two methods was 0.22°C, ranging from 0.32°C (child with no infection or with local infection) and 0.54°C (child with fever in the fastigium phase). The median ranged between 0.30ºC (child with no infection or local infection) and 0.60ºC (child with fever in the fastigium phase; Table 1).

Table 1

Differences between tympanic and axillary temperature values according to the studied variables

	Differences between tympanic and axillary temperature	
	$\bar{x} \pm sd$	Med (Min-Max)
Age (months)		
6 – 12	0.41 ± 0.26	0.40 (0.00 – 1.00)
12 – 24	0.47 ± 0.30	0.50 (0.00 – 1.30)
24 - 36	0,46 ± 0.31	0.50 (0.00 – 1.40)
Gender		
Male	0.44 ± 0.28	0.50 (0.00 – 1.30)
Female	0.46 ± 0.31	0.40 (0.00 – 1.40)
Season		
Spring/summer	0.50 ± 0.30	0.50 (0.00 – 1.40)
Fall/winter	0.41 ± 0.28	0.40 (0.00 – 1.10)
Infection		
Systemic	0.51 ± 0.28	0.50 (0.00 – 1.40)
Local or none	0.32 ± 0.28	0.30 (0.00 – 1.00)
Fever		
Yes	0.52 ± 0.27	0.50 (0.00 – 1.40)
No	0.42 ± 0.30	0.40 (0.00 – 1.20)
Fever stage		
Temperature increase	0.52 ± 0.27	0.50 (0.10 – 1.40)
Plateau phase	0.54 ± 0.25	0.60 (0.00 – 1.00)
Temperature decrease	0.41 ± 0.28	0.40 (0.00 – 1.00)

Note. $\bar{x}$ = Mean; *sd* = standard deviation; Med. = Median; Min. = Minimum; Max. = Maximum.

An effect was observed in the temperature value according to the evaluation method performed in all the variables studied. The analysis of the effect of the interaction of the measurement method with the remaining variables reveals a statistically significant effect of the variables season of the year (hot/cold; $F_{(1)} = 7.892$; $p = 0.005$; $\eta^2_p = 0.02$; PO = 0.80), fever (with or without fever; $F_{(1)} = 6.558$; $p = 0.011$; $\eta^2_p = 0.02$; PO = 0.72) and infection (systemic or local infection/none; $F_{(1)} = 32.692$; p = 0.001; $\eta^2_p = 0.09$; PO = 0.95). It is worth noting that the interaction with these variables is low ($\eta^2_p = 0.02$ for season of the year and with/without fever and $\eta^2_p = 0.09$ for systemic or local infection). In cases where the relationships were not statistically significant ($p > 0.05$), the observed power of the tests is relatively low (< 60%; Table 2).

Table 2

General linear model of the effects on the measurement method and by type of interaction

Variables	F	*p*	η^2_p	OP
Measurement method	788.189	0.001	0.65	0.99
Measurement method * age	1.159	0.315	0.01	0.25
Measurement method	772.309	0.001	0.70	0.99
Measurement method * gender	4.345	0.558	0.01	0.09
Measurement method	469.578	0.001	0.76	0.99
Measurement method * fever stage	2.988	0.053	0.04	0.57
Measurement method	788.189	0.001	0.71	0.99
Measurement method * season	7.892	0.005	0.02	0.80
Measurement method	793.105	0.001	0.71	0.99
Measurement method * with or without fever	6.558	0.011	0.02	0.72
Measurement method	604.502	0.001	0.65	0.99
Measurement method * Systemic and local/no infection	32.692	0.001	0.09	0.95

Note. F = F-test value; η^2_p = Partial eta squared; *p* = p-value; OP = Observed power.

The analysis of agreement by type of interaction reveals a low agreement in the variables fever (with or without fever; ICC 95% (1,2) 0.472 (-0.054 - 0.934; $p < 0.001$) and infection (systemic or local/none); ICC 95% (1,2) 0.631 (0.058 - 0.951; $p < 0.001$). However, these values are acceptable and statistically significant (Table 3).

Table 3

Agreement by type of interaction

	ICC	95% Confidence Interval	*p*
Age			
< 12 months	0.864	0.023 – 0.961	< 0.001
12- 24 months	0.827	- 0.005 – 0.949	
24- 36 months	0.828	0.021 – 0.947	
Gender			
Female	0.810	0.008 – 0.940	< 0.001
Male	0.857	0.020 – 0.958	
Fever stage			
Temperature increase	0.712	- 0.071 – 0.913	< 0.001
Plateau phase	0.776	- 0.058 – 0.941	
Temperature decrease	0.728	- 0.048 – 0.913	
Season			
Hot	0.817	- 0.024 – 0.946	< 0.001
Cold	0.845	0.058 – 0.951	
Infection			
Systemic	0.826	- 0.034 – 0.950	< 0.001
Local / none	0.631	0.011 – 0.844	
Fever			
Yes	0.472	- 0.085 – 0.754	< 0.001
No	0.777	- 0.054 – 0.934	

Note. ICC = Intraclass correlation coefficient; p = p-value.

Discussion

The analysis of body thermometry values by axillary and tympanic routes respecting the DGS (2018) guidelines revealed an almost perfect agreement between these two methods. Because the difference between these two methods is low (less than 1°C), either method does not influence clinical decision-making (Bruel et al., 2020). The largest differences were found in children with fever in the fastigium phase of the fever cycle, the difference being little more than 0.5°C. For this reason, the choice of method for measuring body temperature in clinical practice should consider the acceptance of the method, that is, its advantages and disadvantages to the child, parents, and health professionals. This information was not investigated in this study. Still, given the high agreement between these two methods, future studies should investigate it so that an informed decision can be made for one of these methods for measuring temperature in children. It should be noted that children aged less than 6 months were not included in this study and future investigations should also take this into consideration.
According to the results, temperature measurement in the left armpit in newborns may be an alternative to rectal temperature, minimizing discomfort and the potential risk of bowel perforation (Friedrichs et al., 2013).
In the sample of this study, the temperature measured by the tympanic route was, on average, higher than the axillary temperature, an expected difference of 0.5°C, which is in line with other studies (Oguz et al., 2018). This fact demonstrates the importance of measurement following the DGS (2018) recommendations. However, the need to keep the arm firmly against the trunk for 5 minutes for temperature measurement via the axillary route significantly hinders its acceptability and routine use.
As expected, statistically, the temperature measurement method influenced the temperature value and the effect of the interaction between the measurement method and the variables season of the year, fever/no fever, and infection. These variables (season, fever, and infection) can induce a greater range in the variability of body temperature and, consequently, lower reliability in measurement due to greater dispersion in temperature values.
The lowest agreement between the two temperature measurement methods was found in children with fever, being nevertheless considered moderate and clinically acceptable. Although the literature shows a potential divergence between the core (tympanic) temperature and the peripheral (axillary) temperature of 1 to 3°C (DGS, 2018) during the increment phase, this study revealed

no difference more significant than 1.40ºC.
Many authors consider tympanic thermometry with an infrared thermometer to be the best non-invasive technique to obtain the closest value to the effective core temperature. The only reluctance to use it remains due to the low accuracy of these assessments in children under three months of age, a consequence of the characteristics of the curvature of the ear canal at this age, which hinders the correct positioning of the cannula (El-Radhi, 2014).
Given these results, and given that tympanic temperature measurement is faster and hygienic due to disposable tips, giving it an advantage in pediatric screening services, it is a method to be considered for consistent use in daily clinical practice.
Limitations of this study are the inclusion only of children between 6 and 36 months and the nonexploration of parental preferences regarding the acceptability of the measurement method.
On the other hand, performing the study in different clinical settings would confer greater external validity to the results and allow comparison between other methods for measuring body temperature.
Another critical limitation is non-comparison with a "golden" standard method (core temperature). However, the difficulty of implementing a method for measuring core temperature (invasive) in pediatric clinical settings is recognized.

Conclusion

This study revealed a clinically acceptable agreement between tympanic and axillary body temperature measuring methods in children aged 6 to 36 months.
Either method does not influence clinical decision-making; the choice should consider the advantages and disadvantages of each technique and the preferences of the child (when possible), parents, and health professionals. However, in terms of feasibility and ease of implementation, the advantages of the tympanic evaluation method are superior to the traditional axillary method. They may be adopted as a routine method for temperature assessment in children between 6 and 36 months of age.

Author contributions

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