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Alternative methods to measure body temperature in dogs and cats

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Article

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Abstract

Body temperature (BT) is an important indicator used during physical examination to assess the animal's health and disturbances to its body's homeostasis. Digital rectal thermometry (DRT) is the current gold standard measurement method in small animals' clinical veterinary medicine, surrogating for core body temperature. However, this method has multiple disadvantages, including inaccuracy due to local rectal variations, poor clinicians' safety, animals' discomfort, stress response, and relatively long measuring time. Auricular (tympanic membrane) infrared thermometry (AIRT) could be an attractive alternative, as it represents the hypothalamic temperature well. However, studies assessing its accuracy are scarce and absent in veterinary medicine. This study simultaneously assessed the BT of 100 hospitalized dogs and cats using DRT and AIRT to evaluate the agreement between them, analyzing their accuracy using the coefficient of variation. While DRT was more accurate than AIRT, both methods were reliable, well correlated (R^2 = 0.694), and in good agreement. Measurements by AIRT were mostly lower than by DRT, justifying using a correction factor of 0.5°C, which improved the agreement and correlation between the methods (R^2 = 0.833). Our findings suggest that AIRT was reliable and could substitute DRT when using the latter is impossible or inadvisable.

Introduction

Homeostasis is a self-regulating process in which the homeothermic animal's body maintains its steady state as a stable biological system, including temperature, despite continuous environmental changes [1, 2]. The thermoregulatory system includes the sensation of thermal changes by peripheral and central receptors and involves the spinal cord, midbrain neurons, reticular formation, and the vagus nerve. The system is integrated by the body's main thermoregulatory center in the preoptic zone of the hypothalamus [3, 4]. Heat dissipation/preservation/production mechanisms are activated to maintain the core body temperature (CBT) within its constant narrow physiological range based on the detected temperature [5].

Body temperature (BT) measurement is a basic and important part of physical examination due to its significance to the animal's health. The various BT measurement methods attempt to reflect the real CBT, which can only be measured by invasive methods, e.g., with an esophageal or pulmonary artery thermometer following catheterization [6]. These highly accurate methods are impractical in daily clinical practice as they require animal anesthetization. Nowadays, BT in veterinary medicine is mostly measured in the rectum as a surrogate for CBT. It is usually done by inserting a digital thermometer about 2 cm into the rectum and holding it against the rectal mucosa. This method is routinely and widely used and considered a good and accurate BT measuring approach and a standard of care [6, 7].

However, despite its advantages, this method is not faultless. Rectal thermometry (RT) does not necessarily represent the CBT, as the presence of feces, gas, local inflammation, and local changes in the blood supply might influence it [7]. Although RT is considered the gold standard method for CBT measurement, disagreements between its recordings and the pulmonary artery temperature were shown

[8]. Studies in humans discovered that changes in RT measurements lag behind rapid changes in the CBT [8, 9]. Moreover, RT measurement is considered mildly invasive, might cause discomfort to the animal, and disrupt the rest of the physical examination due to stress, sympathetic stimulation, and annoyance caused to the animal [10].

An alternative, more elegant method to measure BT is by auricular infrared thermometry (AIRT). The thermometer is inserted through the external auditory meatus and measures the heat emanating from the tympanic membrane using pyroelectric sensors. AIRT was first introduced in 1986 for use in humans [11]. Devices suitable for veterinary patients were developed as well. Since the tympanic membrane shares the same carotid artery blood supply with the hypothalamus and no skull bones are present in this anatomic site, it might be an ideal location to noninvasively obtain a BT that represents the hypothalamic temperature accurately. AIRT is considered quick, noninvasive, well-tolerated, and simple. However, its accuracy in human and veterinary medicine remains debated [10, 12].

Research comparing AIRT and digital rectal thermometry (DRT) with a mercury-in-glass thermometer in cats found little differences, with a narrow, clinically acceptable disagreement [12]. In contrast, a study comparing 555 AIRT and DRT measurements in cats found that AIRT was easier, quicker, and had better patient compliance but correlated poorly with DRT and thus was unsuitable as a substitute [13].

A study in humans measuring the tympanic membrane temperature (TMT) with a thermocouple ear thermometer attached to it found that the tympanic membrane was a reliable location to measure the CBT [15]. Likewise, research on 174 human patients compared tympanic membrane IR and axillary mercury-in-glass thermometry [4]. The study found the former to be as accurate as the latter. Therefore, it was suggested that IR tympanic membrane thermometry in humans could be used in clinical practice [4]. In contrast, another research conducted in 2007 in Turkey on pediatric patients found significant statistical and clinical differences between AIRT and mercury-in-glass axillary measurements using the latter as the gold standard CBT measurement [16]. Compared to the axillary measurement, the temperature measured by AIRT was higher in some patients and lower in others. As a result, fever was misdiagnosed in some patients when AIRT was used. Therefore, those authors suggested that AIRT should be used as a screening tool but not as a clinical tool to decide on the patients' treatment.

A meta-analysis comparing AIRT and RT measured with a mercury, electronic, or indwelling probe thermometer found good agreement between the methods in febrile and afebrile children, but the measurements spanned over a wide range, suggesting that AIRT was not a good approximation of RT measurement and, hence, the methods cannot be used interchangeably [17]. While the methods' measurements might differ in humans, studies in veterinary medicine might imply differently. Recently, a study comparing TMT and RT in healthy working dogs found no significant difference between them, both before and after performing routine daily exercise, suggesting that TMT might be a suitable alternative method to monitor BT in exercising dogs [18]. In contrast, a study comparing various BT measurement methods in hospitalized dogs found a higher stress response when DRT was used than when AIRT or an axillary electronic device was used [10].

Considering this information, and the constant technological progress, we aimed to investigate the accuracy and applicability of AIRT in hospitalized febrile and afebrile dogs and cats and establish its suitability as a substitute for the conventional DRT.

Materials and Methods

This study included 100 client-owned pets, 75 dogs and 25 cats, hospitalized in the intensive care unit of our hospital. All methods used in the present study were carried out in accordance with relevant guidelines and regulations of the ethical National Israeli council for the experiments of Pet animal research. Ethical approval was issued by the National Israeli council for the experiments of Pet animal research PET-2023-23-NE.

All measurements were taken by the same person (TB) and were conducted similarly in all cases. RT was measured with a standard veterinary digital thermometer (Vega Technologies Inc., Taipei, Taiwan), which has an accuracy of ± 0.1ºC within a temperature range of 32.0–42.9°C. The thermometer was lubricated with Vaseline (Unilever, London, UK), inserted about 2 cm into the rectal lumen through the anal sphincter, and held against the rectal wall for approximately 30 seconds until the alarm sounded, and a temperature reading was displayed. TMT was measured using an instant infrared ear thermometer for pets (Pet-Temp PT-300, Advanced Monitors Corporation, San Diego, CA, USA). This thermometer has an operating ambient air temperature range of 10–40°C, a measuring range of 34–43°C, and a manufacturer's reported accuracy at room temperature of ± 0.2°C. The probe was covered with a disposable lens cover (Pet-Temp LC-40, Advanced Monitors Corporation). The animal's pinna was pulled backward, and the device was inserted as deep as possible through the external meatus toward the tympanic membrane and held there for 1–2 seconds until the alarm sounded, and a temperature reading was displayed. Measurements were taken consecutively three times, and the average was used for analysis. If a measurement was suspected to be inaccurate due to technical problems (e.g., movement), a fourth measurement was performed and used in its place. All measurements were recorded in degrees Celsius.

Simultaneous blood pressure (BP) measurement was conducted using an automated blood pressure monitor (Vet20, SunTech Medical Inc., Morrisville, NC, USA). An adequate cuff was placed over the fore- or hind-limb of the animal and adjusted to its size. Systolic and diastolic BP readings were taken three times, and the average was recorded.

Anesthesia protocols for sedated animals were adhered to uniformly according to our institutional guidelines. This included premedication with Methadone (0.4 mg/kg) and Midazolam (0.2 mg/kg), followed by intravenous induction with Propofol to effect. All animals were intubated and connected to an anesthetic machine, receiving inhaled Isoflurane (0.5%-2%) during sedation.

Additional pet information retrieved from the medical records included sex, age, body weight, reason for hospitalization, and recent medical treatments.

Statistical analysis

The normality of data distribution was evaluated using Shapiro-Wilk's test for all continuous variables. Normally and non-normally distributed continuous variables are reported as mean and standard deviation or median and range and were compared using Student's *t*-test or Mann-Whitney *U* test, respectively. Device accuracy was assessed by calculating the coefficient of variation (CoV) from 57 triplicate measurements. The cutoff for a satisfying accuracy was 5%.

Spearman's rank or Pearson correlation coefficients were used to assess the correlation between continuous variables. The agreement between the two devices was analyzed using Bland-Altman plots by plotting the temperature difference (RT–TMT, termed rectal-tympanic membrane difference or RTMD) against the mean RT and TMT measured for each subject. Statistical significance was set at $P < 0.05$. Statistical analysis was performed using IBM SPSS Statistics for Windows, Version 22.0 (IBM Corp., Armonk, NY, USA).

Results

Population description

Triplicate DRT and AIRT measurements were obtained from 100 hospitalized animals, 75 dogs and 25 cats (Table 1). The population's median age was 7 (0.25–18) years. The dogs' median age was 8 (1–18) years, and the cats' median age was 5 (0.25–17) years. The median dog weight was 19.3 (2.6–47.0) kg, and the median cat weight was 4.7 (1.4–8.3) kg. The population included 88 conscious (67 dogs, 21 cats) and 12 sedated (8 dogs, 4 cats) animals.

Table 1
Study population description

n	Entire population	Dogs	Cats
	100	**75**	**25**
Females, n	50	38	12
Males, n	50	37	13
Age, median (range), y	7 (0.25–18)	8 (1–18)	5 (0.25–17)
BW, median (range), kg	10 (1.4–47.0)	19.3 (2.6–47.0)	4.7 (1.4–8.3)
Hypotensive, n[a]	14	8	6
Normotensive, n[b]	20	14	6
Hypertensive, n[c]	64	52	12
Conscious, n	88	67	21
Sedated, n	12	8	4
No dipyrone, n	71	51	5
Received dipyrone, n	29	24	5

[a] Hypotensive, mean arterial pressure < 80 mmHg.

[b] Normotensive, mean arterial pressure 80–100 mmHg.

[c] Hypertensive, mean arterial pressure > 100 mmHg.

BW, body weight

The study population was divided into hypertensive (mean arterial pressure [MAP] < 80 mmHg; *n* = 14), normotensive (MAP = 80–100 mmHg; *n* = 20), and hypertensive (MAP > 100 mmHg; *n* = 64). Two BP measurements were not obtained because the animals were uncooperative or restless.

Twenty-nine cases received dipyrone up to eight hours before measurement (24 dogs, 5 cats), and the remaining animals did not (51 dogs, 20 cats; Table 1).

Variability between measurements

The mean CoV was 0.42% (95% confidence interval [CI], 0.31–0.53%) for the DRT measurements and 0.81% (95% CI, 0.62–1.00%) for AIRT, suggesting the devices were highly accurate. However, DRT was significantly more accurate than AIRT ($P < 0.05$).

Measurement outcomes

The median RT measured by DRT in the entire population was 37.8°C (33.4–40.5°C), while the median TMT measured by AIRT was 37.1°C (34.0–40.8°C). Table 2 presents the results for the dogs and cats separately.

Table 2
DRT and AIRT measurement results

n	Entire population	Dogs	Cats
	100	**75**	**25**
DRT, ºC	37.8 (33.4–40.5)	37.9 (34.0–40.5)	37.2 (33.4–39.1)
AIRT, ºC	37.1 (34.0–40.8)	37.1 (34.0–40.8)	37.0 (34.0–39.2)
Values are presented as medians (ranges)			
DRT, digital rectal thermometry; AIRT, auricular infrared thermometry			

Correlation and differences between measurements

The DRT and AIRT measurements correlated significantly (R^2 = 0.694; P < 0.001; Fig. 1). However, measurements differed significantly between DRT and AIRT in the entire population (P < 0.001). The RT was higher than the TMT in 74 cases (74%), lower in 22 (22%), and measurements were the same in 4 (4%; Table 3). The DRT and AIRT measurements differed significantly among dogs (P < 0.001). The RT was higher than the TMT in 71 cases (71%), lower in 24 (24%), and measurements were the same in 5 (5%). The DRT and AIRT measurements differed significantly among cats (P = 0.013). The RT was higher than the TMT in 72 cases (72%) and lower in 28 cases (28%).

Table 3
Differences between RT and TMT for the entire cohort with and without a correction factor for the TMT

Measurement outcome	RT–TMT	RT–TMT + 0.4°C	RT–TMT + 0.5°C
RT > TMT, n (SD)	74 (0.54)	55 (0.44)	51 (0.43)
RT < TMT, n (SD)	22 (0.46)	41 (0.45)	48 (0.47)
RT = TMT, n (SD)	4	4	1
RT, rectal temperature; TMT, tympanic membrane temperature; SD, standard deviation			

The RT and TMT were also assessed by the RTMD. The RTMFD in the entire population was 0.53°C (–2.1 to 2.1°C). Assuming an acceptable difference of up to ± 0.5°C between the devices [19], 43 cases (43%) were within this range. The median RTMD in dogs was 0.56°C (–2.1 to 2.1°C), with 32 measurements

(42.6%) within the ± 0.5ºC range. The median RTMD in cats was 0.4°C (–0.9 to 1.7°C), with 11 measurements (44.0%) within the ± 0.5ºC range.

Correction factor

Previous studies [19, 21] suggested adding 0.4ºC to AIRT as a correction factor. Applying this correction factor to our data resulted in an insignificant difference between the two devices (*P* = 0.126), with the RT higher than the TMT in 55 cases (55%), lower in 41 (41%), and the same in four (4%). When a correction factor of 0.5°C was applied, the similarity between the devices increased (*P* = 0.835), with the RT higher than the TMT in 51 cases (51%), l between measurements to R^2 = 0.833 (P < 0.001).

The differences between the DRT and AIRT measurements (RTMD) were assessed by Bland-Altman analysis and are presented in Table 4 before and after adding the 0.5ºC correction factor. Assessment of these values for the entire population indicated that the RTMD decreased from 0.51 to 0.01ºC after adding the correction factor.

Table 4
Bland-Altman analysis of the RTDM before and after adding the 0.5ºC correction factor

Cohort	*n*	Uncorrected		Corrected (+ 0.5ºC)[a]	
		RTMD (95% CI)[b]	In range[c]	RTMD (95% CI)	In range[c]
Entire cohort	100	0.51 (−0.93 to 1.95)	43 (43.0%)	0.01 (−1.43 to 1.45)	54 (54.0%)
Dogs	75	0.51 (−0.94 to 1.97)	32 (42.6%)	0.01 (−1.44 to 1.47)	40 (53.0%)
Cats	25	0.50 (−0.94 to 1.94)	11 (44.0%)	0.0 (−1.44 to 1.44)	14 (56.0)
Low BP[d]	14	0.51 (−0.84 to 1.87)	6 (42.8%)	0.01 (−1.34 to 1.37)	7 (50.0%)
Normal BP[e]	20	0.41 (−0.78 to 1.59)	10 (50.0%)	−0.09 (−1.28 to 1.09)	14 (70%)
High BP[f]	64	0.56 (−0.97 to 2.09)	27 (42.1%)	0.06 (−1.47 to 1.59)	32 (50.0%)
Hypothermic[g]	55	0.27 (−1.17 to 1.71)	29 (52.7%)	−0.23 (−1.67 to 1.21)	28 (50.9%)
Normothermic[h]	41	0.82 (−0.43 to 2.08)	13 (31.7%)	0.32 (−0.93 to 1.58)	24 (58.5%)

[a] Corrected (+ 0.5ºC), a correction factor of 0.5ºC was added to the auricular infrared thermometry measurements.

[b] RTMD and it 95% CI values are presented in ºC.

[c] In range, number and rate of animals with a measurement difference of up to ± 0.5ºC between the devices.

[d] Low blood pressure (BP), mean arterial pressure < 80 mmHg.

[e] Normal blood pressure (BP), mean arterial pressure 80–100 mmHg.

[f] High blood pressure (BP), mean arterial pressure > 100 mmHg.

[g] Hypothermic, dogs with a digital rectal thermometry measurement < 38.0ºC and cats < 37.8ºC.

[h] Normothermic, dogs with a digital rectal thermometry measurement of 38.0–39.4ºC and 37.8–39.4ºC in cats.

RTMD, rectal-tympanic membrane difference; CI, confidence interval; BP, blood pressure

Discussion

This study that aimed to investigate the accuracy of the devices revealed that DRT and AIRT were satisfactorily reliable, with the mean CoV of both under 5%. DRT (mean CoV = 0.42%) was found to be more accurate than AIRT (mean CoV = 0.81%); however, the AIRT accuracy was good, and it proved to be a reliable tool. Moreover, the two devices were highly correlated (R^2 = 0.694), in line with the moderate to high correlation between the two methods reported in previous studies [10, 14]. The TMT was lower than the RT in most cases, similar to previous reports [7, 10, 19, 20]. However, the correlation between the two methods was improved, and the significant difference between them was abolished when a correction factor was added to AIRT.

The discrepancy between the two methods could be explained by the thermometers' internal bias; however, perhaps there is a physiological explanation for the difference, as measurements by AIRT were mostly lower than by DRT. DRT is an in-contact measuring approach, requiring placing the thermometer in contact with the rectal mucosa inside the rectum for a reliable reading. Conversely, the AIRT is a non-contact device that measures the heat emanating from the tympanic membrane. The body's thermoregulation is influenced by the ambient temperature and depends on many factors, including hydration status, vasodilatation, and vasoconstriction. Consequently, the temperature does not change identically throughout the body in response to thermal changes [21]. For example, the RT might sometimes exceed the CBT or lag significantly behind other body sites in response to changes in the ambient temperature [8, 9, 22]. Research evaluating the TMT in cows showed that it changes rapidly in response to thermal alterations [23]. Consequently, the differences observed between the two measurement methods in this study might represent a true physiological difference between body sites rather than an operator error or inaccuracy in the AIRT.

Using a correction factor improved the agreement between the two methods. Previous studies suggested a correction factor of 0.4°C [21]. However, we found in the current study that adding a correction factor of 0.5°C to the AIRT measurements achieved a higher similarity between the two methods, lowering the difference between them from 0.51°C to 0.01°C and making it insignificant (Table 4).

Another option is to eliminate the need for a correction factor by establishing a new reference range for the AIRT device, as previously suggested [24, 25]. A study aiming to establish a normal TMT reference range using measurements from 157 healthy dogs found that 36.6–38.8°C was s suitable range [25]. However, that study did not include cats, and its findings disagree with the reference values reported by the manufacturer 37.7–39.4°C.

The peripheral thermoregulatory mechanisms include vasodilatation/vasoconstriction, and are stimulated by the preoptic anterior hypothalamus and affected by antipyretic medications (e.g., dipyrone), influencing the CBT and the temperature throughout the body. To analyze the impact of these mechanisms, we divided the study population into various subgroups. We found no difference between the BP subgroups, and dipyrone administration had no impact on the measurement method accuracy, as indicated by the similar RMTD values in the various subgroups.

A primary advantage of measuring the BT with AIRT is its rapidity compared to the DRT. The pet is usually not sedated during the primary physical examination, and DRT measurement should be obtained while the animal is standing still or being restrained for about 30 seconds. Conversely, AIRT takes just 1–2 seconds, lowering the stress without compromising reading accuracy. A study comparing stress response to the use of various BT measuring methods in hospitalized dogs showed a significantly stronger stress response (e.g., increased heart rate), defensive behavior, and vocalization when using DRT than when AIRT or an axillary electronic measurement device was used [10]. Therefore, the main advantage of using AIRT instead of DRT is the reduced stress for both animals and clinicians during BT measurement.

Having said that, positioning the AIRT requires higher accuracy and practice than DRT. When using the DRT, it is important to ensure the thermometer is in contact with the rectal mucosa. With AIRT, the thermometer should be positioned at the correct angle inside the ear canal and directed exactly toward the tympanic membrane. This technique requires practice and, therefore, takes longer to insert the device during the initial attempts. Besides, AIRT might be more expensive than DRT in the long term, as the DRT device should just be lubricated before use, while the AIRT lens should be covered with a specific suitable disposable sleeve. The safety and restraint of the non-sedated animals did not differ much between devices. Similar to DRT, restraint of animals showing signs of aggression required two – one to restrain it and one to take the AIRT measurements. In some cases, the access to the measuring site was affected by the animal's medical condition (e.g., severe diarrhea when using DRT or head bandage after brain neurosurgery when using AIRT), but these situations were case-specific and uncommon.

Some studies evaluating the accuracy of AIRT concluded that it was an unreliable tool and should not be used interchangeably with rectal thermometers [26, 27]. However, some of these studies, especially those performed in humans, used old AIRT devices and compared them to mercury-in-glass thermometers that are rarely used today. Furthermore, while we evaluated only one device, several veterinary AIRT devices are available on the market, and they constantly improve.

In conclusion, the AIRT investigated in the present study might not replace the traditional DRT to measure the BT; however, it could be added as a supplemental tool to widen the range of options for the clinician to choose from based on the patient’s condition and specific needs. It is possible that future BT measuring tools will be adjusted to the animal. When DRT cannot be used (e.g., colitis or perianal or rectal disease), a complete physical examination can still be achieved by substituting DRT with AIRT. At all times, clinicians must be aware of the limitations of their available tools and adhere to their best clinical judgment. Further research is needed to compare several AIRT devices to the gold standard invasive CBT measuring methods in dogs and cats.

Declarations

Declaration of interest statement

The authors declare no competing interests.

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Author Contribution

T.B- leading investigator including writing and planning the research, practical measurements, analysis of the results and statistics and writing the paper.M.H- planning the research program, editing and writing the paper.R.N- planning the research program, statistics analysis, editing and writing the paper.G.S- primary statistics analysis Y.B- leading investigator including planning and conducting the research, writing and submission of the paper.

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Data Availability

All data supporting the findings in the present study is presented in the results part and in the Table and figures. Any raw data will be supplied as needed.

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Figures

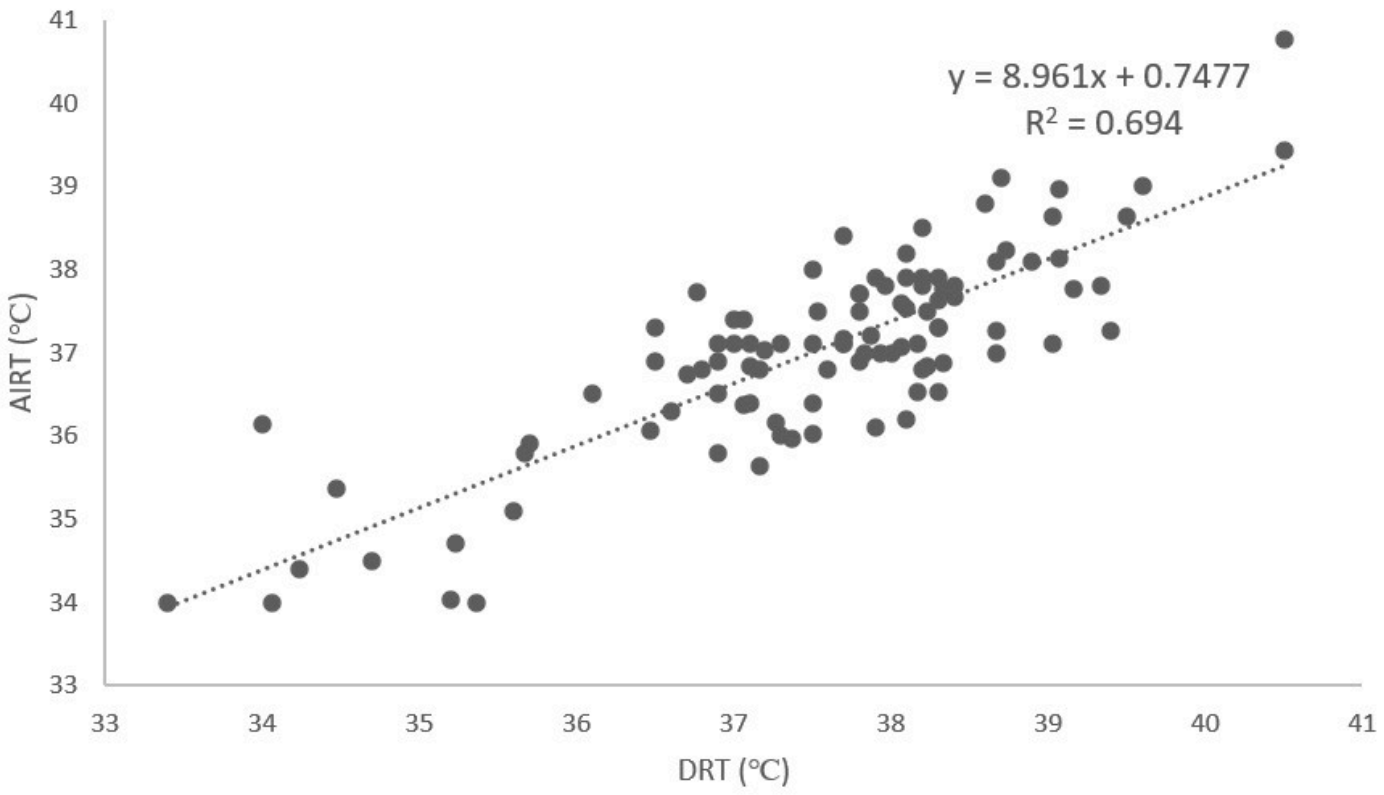


Figure 1

A scatter plot correlating the DRT and AIRT measurements in the entire study population (*N* = 100). The dotted line is the linear regression trendline. R^2 = 0.694; *P* < 0.001. DRT, digital rectal thermometry; AIRT, auricular infrared thermometry