Emily J. Hall MA VetMB AFHEA MRSB MRCVS

Emily qualified as a veterinary surgeon in 2007, and has worked in small animal first opinion practice ever since. Emily now teaches veterinary nursing students on the Foundation degree at Nottingham Trent University and continues to work in practice at weekends.
Email: emily.hall@ ntu.ac.uk

Anne Carter BSc (Hons) MSc PhD FHEA MRSB

Anne has a PhD in canine behaviour and welfare. She continues to research in the field of canine behaviour, welfare and the canine athlete at Nottingham Trent University. Anne course leads the BSc Animal Biology at Nottingham Trent University, in addition to teaching on Anthrozoology and Animal Health & Welfare Masters courses.

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Establishing a reference range for normal canine tympanic membrane temperature measured with a veterinary aural thermometer

Emily J. Hall MA VetMB AFHEA MRSB MRCVS and
Anne Carter BSc (Hons) MSc PhD FHEA MRSB
School of Animal, Rural and Environmental Science, Nottingham Trent University, Brackenhurst, Southwell, Nottinghamshire NG25 0QF, UK

ABSTRACT: Studies have shown that tympanic membrane temperature (TMT) under-reports body temperature when compared to rectal temperature. This could lead to misinterpretation of the TMT, if comparing the result to a rectal temperature range. The aim of this study was to establish a normal canine TMT reference range. Four hundred and sixteen TMTs were taken from 157 healthy dogs, in a range of ambient temperatures. The normal reference range for canine TMT was found to be 36.6–38.8°C. This range should be considered by pet owners and veterinary professionals when interpreting TMT measured with a veterinary aural thermometer, to avoid misinterpretation of the results.

Keywords: dog; body temperature; ear thermometer

Introduction

In both human and veterinary medicine, measuring body temperature remains an important part of any thorough clinical examination. Abnormal body temperature can indicate a range of critical conditions, so it is essential that devices used to measure body temperature are reliable and accurate. Despite considerable scientific advances in digital thermometry and thermography, rectal thermometers remain the gold standard for less-invasive body temperature measurement in veterinary patients, with pulmonary artery, oesophageal and urinary bladder temperatures providing more-invasive but true core temperature measurements. As rectal thermometry can cause stress and require additional restraint in some veterinary patients (Lamb & McBrearty, 2013), there is ongoing interest in developing a reliable, less-invasive method of accurately measuring body temperature. Aural thermometry remains the most promising alternative method of temperature measurement, but recent studies suggest their readings should be interpreted with caution when compared to rectal temperature reference ranges (Gomart et al., 2014; Hall & Carter, 2017; Zanghi, 2016).

There are numerous studies evaluating the use of aural thermometers in dogs, namely the animal-specific PetTemp® and VetTemp® (Advanced Monitors Corporation, California, USA). TMT measurement has been shown to be better tolerated by canine patients in a veterinary setting when compared to rectal thermometry (Gomart et al., 2014; Lamb & McBrearty, 2013), suggesting that for patients where rectal thermometry is impossible due to pathology or patient temperament, TMT can provide a suitable alternative for measuring body temperature (Gomart et al., 2014; Gonzalez et al., 2002; Greer et al., 2007; Hall & Carter, 2017; Lamb & McBrearty, 2013; Rexroat et al., 1999; Southward et al., 2006; Zanghi, 2016). Four of these studies report that

Table 1. Published normal canine rectal reference ranges, their sources and accessibility to pet owners

Source	Accessibility of source	Lower temperature limit	Upper temperature limit
Felder (2016)	Online veterinary manual open access	37.9°C	39.9°C
Miller (2009)	Textbook		39.2°C
Goddard and Phillips (2011)	Textbook	38.2°C	39.2°C
Konietschke et al. (2014)	Open access article	37.2°C	39.2°C

TMT underestimates rectal temperature (Gomart et al., 2014; Hall & Carter, 2017; Southward et al., 2006; Zanghi, 2016), mirroring the findings of Yeoh et al. (2017) in primates. This has important implications when using TMT to measure canine body temperature, because improper interpretation of the readings could result in misdiagnosis and inappropriate treatment.

The PetTemp® manufacturer guidelines recommend using a normal canine and feline TMT range of 37.7–39.4°C (Admon, 1999). This range is not comparable (specifically at the upper limit) to other published temperature reference ranges (see **Table 1**). This lack of consistency defining the normal temperature range is problematic, particularly for pet owners trying to interpret their own dog's body temperature. This variation could reflect the populations of animals used to define "normal canine temperature". If the dogs' temperatures were measured in a veterinary setting, rather than a familiar home environment, stress could increase the animal's body temperature, resulting in an artificially elevated temperature being incorporated into the normal range.

The aim of this study was to determine the normal canine TMT reference range (when measured with a veterinary aural device) using healthy dogs. To provide a suitable sample size, data were pooled from previous projects measuring TMT in resting, healthy dogs. The effect of ambient temperature on TMT was also investigated.

Materials and methods

This study and all previous projects have been approved by Nottingham Trent University's School of Animal, Rural and Environmental Science's ethics approval group.

Animals

The reference population was recruited to try and reflect the general population of pet dogs within the UK, including a range of ages (juvenile to geriatric), both entire and neutered animals of both sex, half of the top 20 pedigree dog breeds in the UK (Kennel Club, 2017) and a number of crossbreeds. All animals recruited to the study were deemed to be fit and healthy by their owner, with no obvious clinical signs or recent history to suggest systemic disease; shivering dogs were not included in the reference population. If otitis externa was present in one ear, the unaffected ear was used for temperature measurement. Although a previous study has shown that there is no significant difference between the TMT measured in dogs' ears with and without otitis externa (Gonzalez et al., 2002), the authors of this paper have found that excessive cerumen or aural discharge can obscure the VetTemp® lens and impact the accuracy. Animals with bilateral ear disease were excluded from the study. All TMT measurements were taken at rest in a non-veterinary environment. Two study populations were used for data collection; the first group includes pet dogs owned largely by members of staff at Nottingham Trent University. These animals were examined indoors, in a familiar environment between June 2015 and June 2017. The second study group were examined outside, prior to competing in a canicross race (dogs harnessed to their owner either running, biking or scootering over approximately 4 km cross-country courses) between November 2015 and April 2017. All data collection took place within the East and West Midlands, UK.

The pet dog population consisted of 32 dogs including 12 females (nine neutered) and 20 males (11 neutered), aged 6 months to 16 years (mean = 6 years). Ten breed types were represented in this sample: spaniel (n = 7), crossbreeds (n = 6), Labrador retriever (n = 5), lurcher (n = 3), collie (n = 3), whippet (n = 2), pug (n = 2), terrier (n = 2), Chihuahua (n = 1) and pointer (n = 1). Body weight was not recorded. TMT measurements were taken in a temperature-controlled environment and dogs were acclimatised to the temperature prior to thermometry.

The canicross dog population consisted of 125 dogs including 52 females (22 neutered) and 73 males (31 neutered), aged 1–10 years old (mean = 4 years). Twenty-five breed types were represented in the sample population, the most numerous being: crossbreed (n = 19), pointer (n = 17), collie (n = 15), spaniel (n = 15), lurcher (n = 7), husky (n = 6), Hungarian vizsla (n = 5), weimaraner (n = 5), other breed types (n = 36). Body weight was not recorded. Ambient temperature was measured prior to TMT measurement and dogs were acclimatised to the ambient conditions prior to thermometry.

In total, the study population included 157 dogs, representing 28 breed types. Some dogs had multiple TMT measurements recorded, range 1–9 readings per dog (mean = 3 readings per dog). For dogs with multiple readings, as each TMT was recorded on a separate day, at a different ambient temperature, for the purpose of analysis each TMT was treated as a separate data point.

An additional 30 dogs were recruited at an outdoor canine event in the West Midlands, UK, held in August 2017 to validate the reference range. The dogs' TMTs were measured at rest using the same selection criteria as the main study population. The validation population included 10 females (four neutered) and 20 males (10 neutered), aged 5.5 months to 14 years (mean = 5 years) and included 14 breed types.

Ambient conditions

Prior to TMT measurement, ambient temperature was recorded. Measurements were taken using a HI 9564 Thermo Hygrometer (Hanna Instruments Ltd, Bedfordshire, UK).

Tympanic membrane temperature measurement

Four new VetTemp® VT-150 Instant Ear Thermometers (Advanced Monitors Corporation, California, USA) were used to measure TMT, as per manufacturer's instructions (see **Figure 1**) covered by a single-use VetTemp® DPC-500 probe cover (Advanced Monitors Corporation, California, USA). The VetTemp® thermometer measures body temperatures between 32.2 and 43.3°C, with an accuracy of ± 0.2°C, within ambient temperatures of 0–40°C. All thermometers were tested reading the surface temperature of a water bath filled with opaque liquid (in an attempt to mimic the surface of the tympanic membrane), and were found to

Figure 1. A VetTemp® aural thermometer in use

read within ± 0.2°C of 36.0°C, 37.0°C and 38.0°C.

All TMT readings were performed by the same investigator, following a standardised method used to examine animals in veterinary practice. Ears used for measurement were chosen based on presentation and restraint of the dog, to reflect the likely situation in practice. Operator accuracy was not formally assessed as part of this study.

Statistical analysis

Statistics were calculated using SPSS 23.0 (SPSS Inc., Chicago, IL, USA). The two populations of dogs were first analysed separately; both populations were found to have a non-parametric distribution and were compared using a Mann–Whitney test. Correlation was tested using Spearman Ranked correlation. The TMTs were then analysed to determine the reference interval, using methods described by Friedrichs et al. (2012). Significance was indicated at $P < 0.05$ for all tests. A histogram was plotted to identify potential outliers, using Dixon's range statistic to determine if outliers should be eliminated from further analysis. As the sample size was over 120 and non-parametric, the percentile method using 90% confidence limits was used to establish the reference limit (Friedrichs et al., 2012). A direct validation method was used, comparing the results from an additional 30 healthy individuals to the calculated reference interval (Friedrichs et al., 2012). More than three readings outside this range would be cause for rejection of the reference interval.

Results

The median indoor temperature was 21.2°C (range 19.0–21.2°C). For outdoor measurements, the median ambient temperature was 8.9°C (range 3.3–16.2°C). During the validation data collection the median temperature was 19.5°C (range 15.4–24.7°C).

One hundred and eight TMT measurements were recorded from the indoor dog population, median TMT = 37.9°C (range 34.3–38.9°C). Three hundred and nine TMT measurements were recorded from the outdoor dog population, median TMT = 37.7°C (range 36.2–39.1°C).

There was no significant difference between indoor versus outdoor TMT measurements ($Z = -1.679$, $P = 0.093$), therefore all data were pooled for further analysis.

The pooled data were then analysed to establish a reference range, with one outlier removed (TMT = 34.3°C) following identification using Dixon's outlier range statistic (Friedrichs et al., 2012). Four hundred and sixteen TMT readings were used for the reference interval calculation. The reference interval for healthy canine TMT was calculated from 416 TMT readings, and was shown to range from 36.6 to 38.8°C (confidence interval [CI] = 36.5–36.7°C at the lower limit, CI = 38.8–38.9°C at the upper limit). There was no significant correlation between ambient temperature and TMT ($R_s = -0.007$, $P = 0.894$) (see **Figure 2**). Additionally, there was no significant difference between the resting TMTs of males and females ($Z = -0.578$, $P = 0.564$).

Validation

TMT readings from the 30 dogs in the validation population all fell within this reference interval (36.6–38.8°C), with a median TMT of 37.9°C (range 37.0–38.5°C). The reference interval was therefore accepted.

Discussion

When measured with a veterinary aural thermometer, the normal range of TMT in healthy dogs was found to be 36.6–38.8°C. This is lower than the range of 37.7–39.4°C stated by the thermometer manufacturer (Admon, 1999). Continued use of the manufacturer's recommended temperature range or published canine rectal temperature ranges could result in hypothermia being over-diagnosed, hyperthermia being missed and patients being inappropriately treated.

As the PetTemp® is marketed specifically to pet owners as a means of measuring their dog's temperature, it is essential that owners understand how to interpret the results for their animal. Global warming is impacting the frequency of unseasonal heatwaves (WMO, 2016), increasing the risk of heatstroke in all species, but particularly dogs as their ability to lose heat is quickly impaired as temperature and humidity increase (Hemmelgarn and Gannon, 2013). A dog owner may use their animal's body temperature to reach a decision about seeking veterinary advice for heat-related diseases, or how to manage their animal's competition or training. The reference range for canine TMT suggested in this study should reduce the likelihood of hyperthermia being missed, ensuring owners are not falsely reassured by a "normal" temperature measurement potentially putting their animal at risk.

As this study only recorded TMT, with no rectal or core temperature measurement with which to compare the results, there is a possibility some of the animals measured were not normothermic when assessed. Therefore, nothing can be said about the accuracy of the thermometry device from this study alone. Ideally, TMT would have been measured alongside rectal thermometry; however, this could have affected the dog's body temperature through stress. Additionally, requiring dogs to have rectal thermometry and aural thermometry performed would have limited the number of dogs recruited to the outdoor study.

While the establishment of a normal canine TMT reference range should improve the interpretation of TMT, it is important to acknowledge the limitations of TMT measurement as a clinical tool. Aural thermometers have been shown to result in more variation than rectal thermometry when operator accuracy has been investigated formally (Greer et al., 2007). This degree of inaccuracy is one of the reasons aural thermometers cannot replace rectal thermometers as the routine method of measuring body temperature in clinical patients. The tympanic membrane does not have a consistent temperature in primates (Yeoh et al., 2017), and variations between the anatomy of different dog breeds could result in a lack of consistency of probe placement. These factors could explain the reported variability of TMT when compared to rectal temperature (Lamb and McBrearty, 2013). It is also essential that the disposable probe covers are used, and changed between every patient. This not only prevents potential transmission of infections between patients, but also protects the probe from accumulation of debris which can reduce accuracy of the device (Admon, 1999).

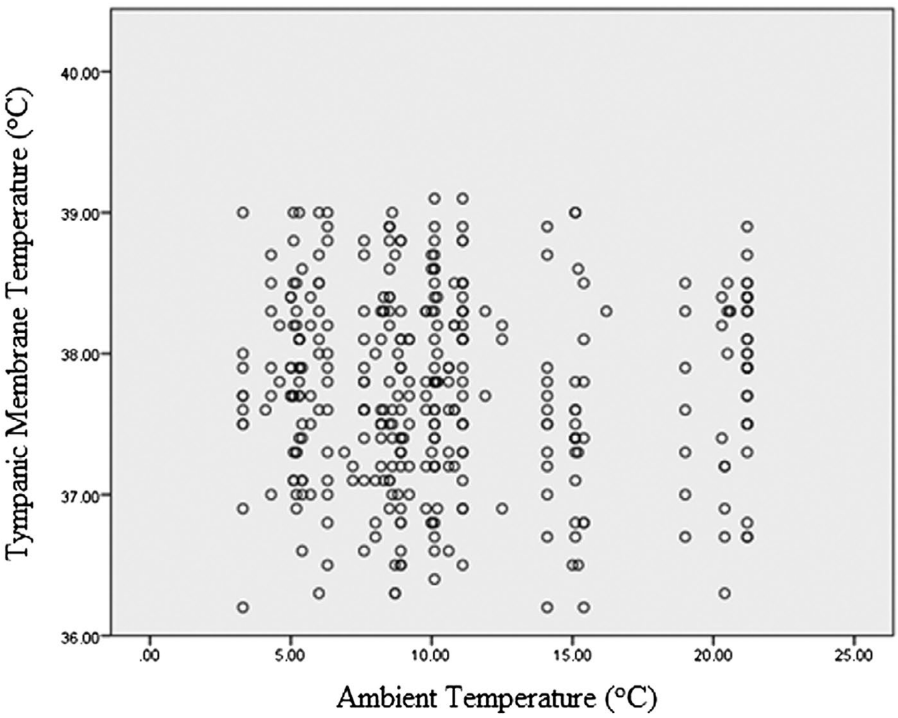

Figure 2. Scatter plot of the ambient temperature versus tympanic membrane temperature of healthy dogs

Although the use of human aural thermometers has been investigated in dogs, the shape of the probe is considerably different to that of the veterinary-specific devices (see **Figure 3**), meaning in many dogs the human thermometer is likely to be reading the skin lining the ear canal, rather than the tympanic membrane (Greer et al., 2007). The reference range established in this study is therefore unlikely to be accurate when used to interpret results from a human ear thermometer.

As this study measured TMT in a non-veterinary setting, additional work establishing a reference range in veterinary patients would be beneficial. The stress of visiting a veterinary practice can elevate body temperature; establishing how this affects the upper end of the reference range could aid veterinary professionals in interpretation of the temperature measurements.

Figure 3. A human aural thermometer alongside a VetTemp® aural thermometer with probe cover in place

Conclusion

The findings of this study would support a normal canine TMT reference range of 36.8–38.8°C. This is in line with previous research reporting that TMT reads approximately 0.4°C below rectal temperature (Gomart et al., 2014; Hall & Carter, 2017; Zanghi, 2016), when using a normal rectal temperature range of 37.2–39.2°C (Konietschke et al., 2014). TMT is a useful screening tool to assess body temperature in dogs; however, as TMT is not as reliable as rectal thermometry, when monitoring clinical patients TMT measurement should be followed up by rectal thermometry should hypo- or hyperthermia be detected.

ORCID

Emily J. Hall http://orcid.org/0000-0002-9978-8736

Anne Carter http://orcid.org/0000-0002-6216-2377

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Appendix

Establishing a reference range for normal canine tympanic membrane temperature measured with a veterinary aural thermometer

Glossary

Non-parametric distribution: data with a parametric (or normal) distribution, when plotted in a histogram forms a roughly bell-shaped curved, with a symmetrical distribution of data points around the mean. Non-parametric data does not fit this normal distribution. Figure A1 shows the histogram for this study, the mean is marked with a black circle, the data is not symmetrically spread around the mean as there is a wider range below the mean than above. A statistical test is also used, the Shapiro–Wilkes test, to confirm that the data are not normally distributed.

Mann–Whitney test: this statistical test is used to analyse non-parametric data, comparing two experimental conditions when there are not even numbers of samples in each group, in this example indoor versus outdoor TMT readings, and male versus female TMT readings.

Dixon's range statistic: this is one method of identifying outliers in a data set. A histogram is plotted, any data points lying outside the main population are investigated further (see Figure A1, there is one data point at 34.3°C). The Dixon's range statistic is then calculated by first measuring the overall range of the whole data set, so 39.1 – 34.3°C = 4.8°C (this is called the R value, the range of the data set). Next, the difference between the suspected outlier, and the next closest value is calculated, so 36.2 – 34.3°C = 1.9°C (this s called the D value, the difference of the suspected outlier to the main data set). If D/R > 0.3 (the difference, divided by the range is greater than 0.3) then the data point is considered an outlier, and can be removed from the data set. In this case, 1.9°C / 4.8°C = 0.4, so the outlier was removed.

Percentile method: there are many ways of determining a reference range, depending on the data set being used. Normality and sample size determine which method should be used, in this paper a sample size over 120, and a non-parametric distribution required the percentile method. This method excludes a percentage of the highest and the lowest values recorded to exclude the most extreme values.

Confidence limits: in an ideal world, to establish the absolute canine temperature reference range you would take the temperature of every single healthy dog in the UK. As this is almost impossible, instead, a sample of the population is measured. This sample is then used to calculate the reference range, meaning there is a degree of uncertainty about the accuracy of this resulting range. Confidence limits aim to illustrate this uncertainty, providing the maximum and minimum values either side of the statistic of interest, based on the overall distribution of data. In this study for example, the lower end of the calculated reference range is 36.6°C, the confidence interval is 36.5–36.7°C, demonstrating ± 0.1°C of uncertainty around this value. At the upper end of the reference range, 38.8°C, the confidence interval is 38.8–38.9°C, demonstrating slightly more confidence in this value.

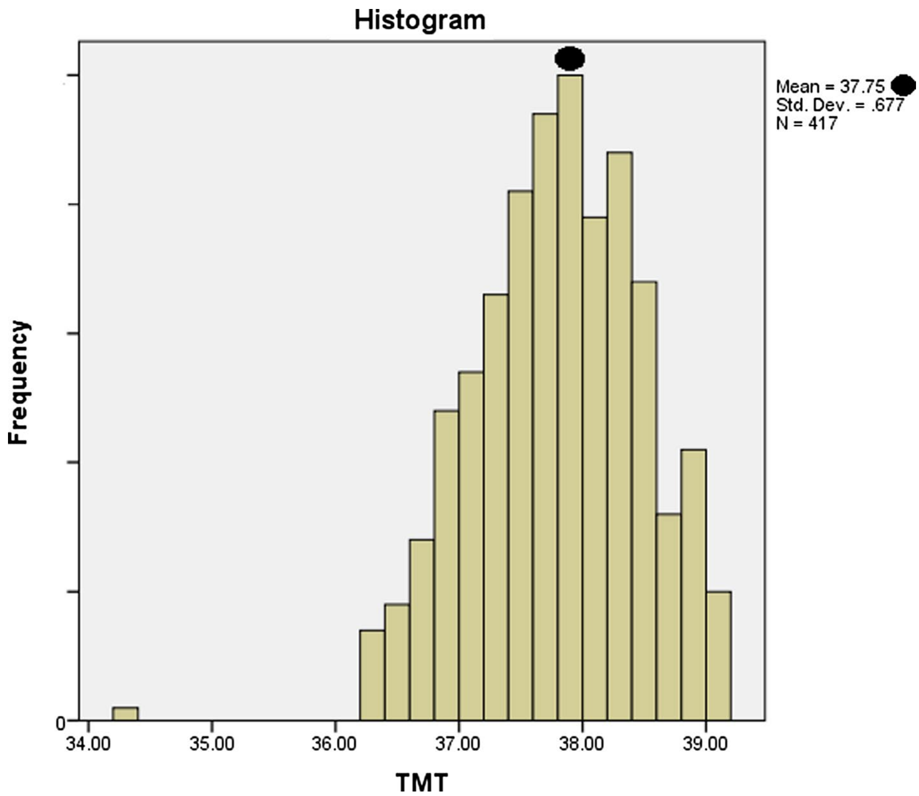

Figure A1. The histogram of the overall study population used to calculate tympanic membrane temperature (TMT) reference range in healthy dogs. The mean is highlighted using the black circle. One possible outlier can be seen at 34.3°C