**BODY TEMPERATURE: Individual body temperature variations and how to assess them**

Body temperature is a fundamental clinical parameter in human and veterinary medicine. Fever and its concomitant signs have been known since Hippocrates and since that time doctors and scientists have sought how best to measure it and with a variety of methods. However, the causes of variation in body temperature are numerous and not all are pathological.

## Does a normal temperature exist?

The commonly accepted "normal" body temperature in humans is 37°C (98.6°F). This value was defined by the German physician Dr Carl Wunderlich who, in the 19th century, collected one million axillary temperature measurements from 25,000 patients. Based on these measurements, Dr Wunderlich concluded that the "normal" human body temperature lay between 37 and 37.5°C (98.6 and 99.5°F).

Many later studies showed that numerous non-pathological factors, such as age (temperature in the elderly is lower than in adults, which is lower than in children) (Anonymous, 2006), the time of day (body temperature can increase by one degree Celsius during the day) or being overweight cause variations in body temperature (Piccione *et al*, 2011).

The notion of "normal" body temperature must therefore be nuanced, and it would be more accurate to refer to an individual "profile" for each patient, based on several measurements taken during the course of one day and on several other days, before deciding that the patient is really suffering from higher (hyperthermia) or lower (hypothermia) body temperature than its own profile and seeking its cause.

## The influence of circadian rhythm

Circadian rhythm is an approximately 24-hour biological pattern that has at least one cycle per 24-hour period. Circadian rhythms are regulated by internal clocks (chronobiology is the science which studies these rhythms). In mammals, these are controlled by the suprachiasmatic nuclei located in the hypothalamus. Not only do all species of animal have circadian rhythms but plants do too.

Body temperature, in common with most essential physiological functions (heart and respiration rate, blood pressure, sleep/wake cycle, bone metabolism, hormone production, nail growth, etc.), also follows a circadian rhythm. A 2003 study demonstrated this phenomenon in dogs for the first time (Refinetti and Piccione, 2003). Rectal temperature was measured every 2 hours for 1 week in seven female Beagle dogs. The dogs were kept under rigorously controlled conditions including ambient temperature (21°C ± 2°C, around 70°F), lighting (600 lux from 6 am to 6 pm), limited exercise and the same diet (provided at 10 am). Mean rectal temperature in this study was 39.1°C (102.4°F), which is 0.2°C (0.4°F) above the body temperature (38.9°C or 102.0°F) generally considered "normal" in dogs. The data from all seven dogs supported the same conclusions: body temperature started to increase immediately after feeding and lasted until lights-out, 8 hours later. Feeding was not the cause of the day-long increase in body temperature. The environmental conditions were strictly controlled and therefore could not have been the cause of body temperature increase; this means that the only cause of the change was endogenous.

In 2009, another team studied the onset of circadian rhythms of rectal temperature, heart rate and respiratory rate in newborn puppies from three different breeds of dog with radically different growth rates: Rottweiler, Cocker spaniel and Pug (Piccione *et al*, 2010). The three litters of puppies were maintained under identical conditions with controlled ambient temperature, humidity and lighting. Rectal temperature, heart rate and respiratory rate were measured at 3-hour intervals for 48 hours starting at 8 am. The series of measurements were repeated every 7 days from day 7 to days 63-64 after birth. During the first weeks of life, the body temperature of all puppies increased steadily, reflecting the gradual development of thermoregulation. Moreover, a circadian rhythm of body temperature appeared 4 weeks after birth, irrespective of the breed of dog. This rhythm developed sooner than those for heart rate and respiratory rate, which started 2 months after birth, and was unrelated to those of the dam.

**Other factors influencing body temperature variation**

External (environmental) and individual factors also lead to variation in body temperature. For example, an Italian study published in 2011 sought to determine a correlation between obesity and body temperature in dogs (Piccione *et al*, 2011).. The authors measured rectal temperature in 287 dogs of different breed, body weight, sex and age, in the laboratory and under field conditions. The results clearly show a correlation between body size and body temperature: the greater the body weight of the dog, the lower the body temperature. Moreover, for the same body weights, obese dogs had a lower rectal temperature than lean dogs.

In 2012, another Italian team showed the effect of moderate physical exercise on various body parameters, including body temperature in untrained Beagle dogs (Piccione *et al*, 2012). Seven male Beagle dogs were walked, trotted and walked on a treadmill. Rectal body temperature was measured at rest, after each of the different phases of exercise and after a 30-minute rest. As expected, the body temperature increased during exercise and had decreased again after the recovery phase. This is because the heat produced by the muscles during physical exercise temporarily exceeds the body's ability to disperse it, which results in an increase in body temperature.

Other causes of body temperature variation, such as age or outside temperature have been shown in humans. These are non-pathological causes. However, the whole point of measuring a patient's temperature is the ability to detect pathological variations as early as possible. Although fever is a frequent, early and easy-to-measure clinical sign, it is non-specific and can be the result of more than 200 human illnesses. In 2012, a French retrospective study investigated the causes of fever in dogs (Chervier *et al*,2012). Non-infectious inflammatory disease is the cause of 48% of cases of hyperthermia in dogs, far exceeding infectious disease and neoplasia. True cases of fever of unknown origin are likely to be quite rare, assuming that the owner agrees to carry out the recommended additional tests to support reaching a diagnosis. No correlation was found between the three major groups of pathologies and the intensity or profile of the hyperthermia. In cats, infection remains the most common cause of hyperthermia (Harkin, 2017).

**Measuring instruments**

Fever and its associated clinical signs have always been of great importance in human medicine, and the first tools for measuring body temperature date back to the 16th century. Ideally, the body temperature should be measured at the thermoregulatory center located in the hypothalamus, but this is obviously not feasible. Rectal temperature measurement remains the gold standard as it is supposed to best reflect body temperature and is familiar to veterinarians. However, this method may be stressful for the animal and has a number of drawbacks: the potential for causing cross-contamination, alteration of the measurement by various phenomena, such as digestion, increased peristalsis, a fecal mass or by insufficient depth of introduction of the thermometer. In addition, this method is unsuitable for herd or flock medicine because it is time-consuming, dangerous and sometimes even impossible, if the rectal temperatures of every animal needs to be measured (in particular in breeding, rescue or wild animals).

Thus, many studies have aimed to find another technique for measuring body temperature. Ear thermometers have been tested in several studies (Sousa, 2016). This would appear to be less stressful than using a rectal thermometer, but measurements are erratic.

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In 2011, an American team used an ingestible temperature sensor to monitor body temperature in dogs during exercise (Angle and Gillette, 2011). This method has some clear advantages: no restraint is needed meaning that there is little stress for the animal once the sensor has been ingested, remote measurements without the need to immobilize the dog during exercise, and an unlimited number of measurements. However, the sensor is temporary as it passes through the dog's gastrointestinal tract.

In 2012 a US research group sought to demonstrate a correlation between rectal temperature and peripheral temperature (measured using an electronic transponder (Thermochip®microchip) that is able to measure temperature at the subcutaneous implantation site) in a fever model in young Holstein steers (Reid *et al*, 2012). There was no correlation between rectal temperature and subcutaneous temperature regardless of the site of implantation of the microchip (posterior to the poll, beneath the umbilical fold, or behind the ear cartilage). However, the study reveals that subcutaneous temperature measurement is of value for various reasons: implantation of the transponder is easy and veterinarians are experienced with this technique, the transponder remains permanently in situ, readings are easy to take (only using an enhanced microchip reader) and therefore without physical or time constraints. By using this transponder to take repeated subcutaneous temperature measurements, it is possible to establish an individual temperature profile for each animal and thus to detect any unusual variation.

**Conclusion:**

A consistent number of studies published in Human and in Veterinary Medicines over the last 40 years pointed out the challenges to find a method for measuring temperature that would correlate with rectal temperature (Sousa, 2016).

Perhaps we should just stop referring to rectal temperature as the unique way to assess "real" body temperature. While rectal temperature is still considered to be the gold standard, we think that we know what "the normal range" is, but do we really? We should first ensure that we know each pet's individual temperature range, in order to interpret temperature variations correctly and improve the detection of pathologies.

If another method of assessing temperature variations was available, easier and just as reliable, this would encourage us to change our established routines. We could then develop new standards that would be more adapted to each pet's individual temperature range. Actually this technology already exists: Thermochip® is a once in a lifetime technology, that makes subcutaneous temperature monitoring quick and easy.

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