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REFERENCE RANGE OF BODY TEMPERATURE IN SUDAN

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ABSTRACT

Constancy of core body temperature is a hallmark of its intact. Measuring body temperature is a routine process made by clinicians for diagnosis and prescribing the treatment. Establishing a reference range of body temperature as well as its diurnal variation in Sudanese community orally was the objective of this cross-sectional research. Two-hundred-thirty-five apparently fit subjects (202 males and 33 females) aged 18 to 50 years were enrolled during mid-January to first March, 2007. The study was conducted at Alfashir city - West Sudan; among University students, army residents, and Quran students. A questionnaire was used to exclude temperature disturbance cases. Oral temperature was measured in the morning and the evening by mercury-in-glass thermometer, and then mean oral temperature (MOT) and its diurnal variation (DV) were obtained by analyzing the measured data with statistical programme for social sciences (SPSS) and software t-test. The MOT and its DV were found to be 36.47 ± 0.35^oC and 0.94 ± 0.61^oC respectively. The data showed significant relation of body temperature with both sex (more in females) and age ($p = 0.001$) with its decrease in elderly. The values of MOT and its DV in January and February (to beginning of March) were 36.43 ± 0.99^oC and 36.79 ± 0.53^oC respectively. The study indicated 36.5 ± 0.9^oC as a reference mean body temperature among Sudanese population. The women and young ages appear to have high body temperatures. The reverse values between MOT and its DV as showed by the study deserves further work.

KEYWORDS: Reference range, body temperature, diurnal variation, Sudan.

INTRODUCTION

Almost all plants and animals show cyclic variations in many of their functions. There are cycles of many different durations, but the most prominent are those about 24 hours long, the circadian or diurnal rhythms. In animals and humans, the circadian fluctuations in body temperature, adrenocortical functions, Na^+ and K^+ excretion, and urine volume are among the best known, there are many others. Although detailed discussion of these rhythms except body temperature is out the scope of this study, it ispertinent that the "biologic clocks" controlling some of them are apparently located in the limbic system. Abnormalities of sleep-wakefulness cycles and body temperature cycles without hypothermia (below 35^oC) or hyperthermia (above 37^oC) have been reported after limbic lesions (1).

There are only minor circadian rhythms among thyroid hormones. Immunoassays for total thyroxine (TT_4), free T_4 (FT_4), total triiodothyronine (TT_3), tree T_3 (FT_3) and thyroid-stimulating hormone (TSH) are widely available, and measurements may be made at any time (2).

Ln this study investigator wants to establish the value of diurnal variation in body temperature orally by using mercury-in-glass thermometers on both normal and hyperthyroid subjects of ages from 18 to 50 years at Al-Fashir city, Sudan. A descriptive cross sectional study is designed for data collection.

Mean morning, mean evening and the general mean oral temperatures are measured before estimating diurnal variation in body temperature for all subjects under the study. A questionnaire is used to exclude individuals having febrile diseases or any fever-inducing causes. Diurnal variation in oral temperature is expected to be lower in hyperthyroid patients, because of sustained increase in their body temperatures due to continual increase in basal metabolic rate (BMR). In contrary, the diurnal temperature variation in normal subjects is expected to be higher than in hyperthyroid patients, because of the lack of similar increase in BMR as in the patients. But its magnitude depends on physiological (e.g. age, gender, time of day and season of the year) and pathological (e.g. fever) factors (3).

THEORETICAL BACKGROUND

DEFINITION OFNORMALBODYTEMPERATURE

The measurement of body heat is a measure of body's ability to generate and get rid of heat. The body is very accurate in keeping its temperature within a narrow and safe range in spite of large variations in environmental temperatures. When body temperature increases, the blood vessels in the skin expand (dilate) to carry the excess heat to the skin's surface. A person may begin to sweat, and the sweat evaporates to cool the body. When the person is too cold, his blood vessels narrow (contract) so that blood flow to his skin is reduced to conserve body heat. He may start shivering, which is an involuntary and rapid contraction of muscles. This extra muscle activity helps generate more heat. Under normal conditions, this keeps the temperature within a narrow and safe range (4).

SOMENORMAL VALUES OF ORAL TEMPERATURE

In the late 19th century Wunderlich et al measured axillary temperature in healthy adults between 36.2 and 37.5^{o}C, with 37^{o}Cas the mean temperature and people accepted this as" normal" body temperature (5). But now people found that Wunderlich's thermometers were 1.4 to 2.2^{o}C higher than today's thermometers (6). More recent studies measured mean body temperature in healthy subjects aged 18 – 40 years around 36.8^{o}C (7) and 36.86^{o}C in subjects aged 64 years and older (8). No single core temperature level can be considered to be normal, because measurements in many normal people have shown a range of normal temperatures measured orally, from less than 97^{o}F (36^{o}C) to over 99.5^{o}F (37.5^{o}C). The average normal core temperature is generally considered to be between 98.0^{o}F and 98.6^{o}F when measured orally. It remains almost exactly constant, with ±1^{o}F (± 0.6^{o}C), day in and day out except when a person develops a febrile illness (9). Body temperature rises about half an hour after meals and reaches is peak after about 1.5 hours; whereas a slight rise (0.2 – 0.3^{o}C) occurs at the time of ovulation. In homoeothermic animals, the actual temperature at which the body is maintained varies from species to species and to a lesser degree from individual to individual. In humans, the traditional normal value for oral temperature is 37^{o}C, with a standard deviation of 0.2^{o}C. Therefore, 95% of all young adults would be expected to have a morning oral temperature of 36.3 – 37.1^{o}C (97.8 – 98.8^{o}F); mean ± 1.96 standard deviation. Temperature is less precise in young children, and they may normally have temperature that is 0.5^{o}C or so above the established normal adults' temperature, some apparently normal adults chronically have a temperature above the normal range (constitutional hyperthermia) (10). Elderly people (61-71 years) have temperature distribution with peaks close to 36.5^{o}C and 35.8^{o}C (11). Measurement of body temperature is used in the following situations (4):

- Detecting abnormally low body temperature (hypothermia) in people who have been exposed to cold.
- Detecting abnormally high body temperature (hyperthermia) in people who have been exposed to heat or having fever.
- Monitoring the effectiveness of fever-reducing medications.
- Planning pregnancy by determining if a woman is ovulating.
- Making a differential diagnosis in a doubtful case of thyrotoxicosis, it is significant if the patient is not losing weight, and does not suffer from increased appetite.

REGULATION OF HUMAN BODY TEMPERATURE

Heat is produced and lost by the following processes (12):

Heat production: Heat is produced by:

- Ingestion of food.
- Contraction of skeletal muscles.
- Hormonal secretion, epinephrine, and thyroid hormones.
- Brown fat in infants.
-

Heat loss: The processes of heat loss are:

- Conduction: heat exchange between objects or subjects.
- Convection: the movement of molecules away from area of contact.
- Radiation: transfer of heat by infrared radiation from one object to another at different temperatures, with which is not in contact.
- Vaporization of water in sweat and through respiration.
- Small amounts of heat are lost in the urine and feces.

The balance between heat production and heat loss determines the body temperature. Normal body function depends on a relatively constant body temperature that is influenced by physiological (e. g. time at day, age and gender) and pathological (e. g. fever) factors[3].

ALTERED TEMPERATURES

Disturbances in heat regulating mechanisms will cause a low body temperature or a high body temperature.

Hypothermia

Humans tolerate body temperatures of 21 – 24^{o}C (70 – 75^{o}F) without permanent ill effect, and induced hypothermia has been used extensively in surgery. In hypothermic patients, the circulation can be stopped for relatively long period, because the O_2 needs of the tissues are greatly reduced. It is possible under hypothermia to stop and open the heart and perform other processes, especially brain operations that would have been impossible without cooling. On the other hand, accidental hypothermia due to prolonged exposure to cold air or cold water is a serious condition and requires careful monitoring and prompt rewarming (10). Also tissue should be obtained as soon as possible after death and may be stored at -20^{o}C for a year (13). In the cold, body temperature is maintained in the young by greater pre-shivering and shivering thermogenesis (11). Hypothermia may occur from:

- Certain metabolic disorders, such as hypothyroidism and panhypopitutarism.
- Shock states, e.g. following severe hemorrhage or burns.
- Starvation and chronic debilitating diseases.
- Damage to the anterior hypothalamus.
- Old age, aging is associated with diminished cold-induced thermoregulation.

The mechanisms accounting for this phenomenonhave yet to be clearly elucidated but most likely reflect a combination of increased heat loss and decreased metabolic heat production. The inability of the aged subjects to reduce heat loss during cold exposure is associated with diminished reactive tone of the cutaneous vasculature and to a lesser degree, alterations in the insulative properties of the body fat (14).

Fever

In most adults, oral temperature above 100^{o}F (37^{o}C) is considered a fever, which is most universally known as a hallmark of disease (10) or a characteristic increase in core body temperature by 1 – 4^{o}C due to infection (15). Fever may occur as a reaction to:

- Infection. This is the most common cause of fever, infections may affect the whole body or a specific body part (localized infection).
- Medications, such as antibiotics, narcotics, barbiturates, antihistamines, and many others. These are called drug fevers. Some medications such as antibiotics raise the body temperature directly; others interfere with the body's ability to readjust its temperature when other factors cause it to rise.
- Severe trauma or injury, such as a heart attack and stroke, heat exhaustion or heatstroke, or burns.
- Other medical conditions such as hyperthyroidism.

FACTORS AFFECTING NORMAL BODY TEMPERATURE

Most people think of a "normal" body temperature as an oral temperature of 98.6^{o}F (37^{o}C). This is not always so, but depends on several variables as (4):

Diurnal variation

Circadian rhythms (ie. diurnal variations) are biological functions of approximately 24 hours length and are significant sources of body temperature variations. The daily pattern of body temperature is the most widely assessed circadian rhythm in chronological studies. It is usually considered a "marker rhythm" that is used to determine time on an individual body's clock and as a reference point to determine whether other rhythms are synchronized or desynchronized (16). Different values of diurnal variation are discussed. The normal body temperature undergoes a regular circadian fluctuation of 0.5 – 0.7^{o}C. In individuals who sleep at night and are awake during the day (even when hospitalized at bed rest), it is lowest at about 6:00 AM and highest in the evenings. It is lowest during sleep, is slightly higher in the awake but relaxed state, and rises with activity (10). The circadian pattern of oral temperature rises by 0.3^{o}C from 09h00 to 23h00 in both young and elderly subjects, and significantly falls to about 0.4^{o}C (elderly) and about 0.8^{o}C (young)during the night and 03h00.The stability of the circadian body temperature rhythm comes about because of the large endogenous components it possesses(11). However, the core body temperature stays within a range of 1 – 2^{o}C throughout the day (15).

Age

The thermoregulation of core body temperature is influenced by physiological factors, e.g. age[3]. Newborns have higher mean oral temperatures than adults (0.4^{o}C) while elderly nursing home patients have lower mean temperatures than healthy young adults (0.2^{o}C). There is a decrement in normal resting body temperature with age, it might imply that ability temperature control in elderly subjects could involve a resetting, or change of gain of the central nervous control of thermoregulation (11). Adult body temperature lies within a range of time-dependent possible values; however, this range might be influenced by age. There is some evidence that daily temperature midway between the highest and lowest values (mesor), and the difference between the maximum highest value of the wave and the rhythmic-adjusted mean of the wave form (amplitude) decreases with age (16). Whereas oral temperature in 65 – 80 years old women ranges from 35.9 – 36.8^{o}C with group mean amplitude of 0.3^{o}C, resulting in an average peak difference of 0.58^{o}C (Mason, 1988). Young adults have a higher mesor (36 – 38^{o}C) than in older subjects (36.17^{o}C), with decrease amplitude in elderly subjects. The mean circadian rhythm is similar in both age groups (17).

Gender

Thermoregulation of core body temperature is influenced by gender in addition to other physiological factors (3). For example, after heat stress a woman will have higher skin temperatures and lower sweat rates than men, but when subjects were matched for body fatness, heat storage and tolerance time, there was no difference between genders(18). Some gender-related differences may be caused by different body composition and anthropometry (19) as well as hormonal differences, body water regulation, exercise capacity (20). Some studies found no significant gender-related differences among elderly white men and women (8).

Site of measurement

Temperature can be monitored at different sites, with the choice of site resulting in certain trade-offs in terms of convenience and reliability. As example, oral temperature is generally considered to be extremely convenient and reliable (21). A rectal temperature (representative core temperature) reading is 0.5 to 1^{o}F (0.3 to 0.6^{o}C) higher than an oral temperature reading. A temperature taken in the armpit is 0.5 to 1^{o}F (0.3 to 0.6^{o}C) lower than an oral temperature reading[4]. Some studies regarding sites of temperature measurement are discussed. Monitoring temperatures of 100 individuals, including 26 had found ranging from 37.3 – 40.5^{o}C. Oral temperature was higher than axillary in all cases with no correlation between them (22). Whereas reporting on rectal, oral, and tympanic membrane temperature measurements from 22 healthy subjects, found mean rectal temperature exceeded concurrent oral readings by 0.4^{o}C and 0.8^{o}C for tympanic membrane readings (23).

Season of the year

Several studies suggest that the time of year might be a possible source of temperature variability; however, observations from available studies are inconsistent. The lack of agreement might be secondary to the site monitored, the population studied, geography, ambient temperatures or other confounding factors (16). Monitoring oral temperature in 26 subjects in December, March, and June (in males) showed average daily the same temperatures in all three months: however, females' average oral temperatures decreased slightly from March (36.9^{o}C) to June (36.8^{o}C) to December (36.72^{o}C). Temperature change from waking to acrophase (measure of the crest time of a rhythm) was reduced in June compared with December, suggesting the temperature amplitude might be diminished in summer compared with the winter season. The acrophase of peak body temperatures occurred slightly later in the day in March (~20:00) and June (~20:00) than in December (~19:00)(24). Another study of young healthy male adults in June and December came with the results of an increase in the mesor of daily measurements in June (37.10°C) compared with December (36.85°C). Daily amplitude of temperature was also greater in June (1.37°C) than in December (0.85°C) (25). Also another seasonal study showed higher individual and group temperature levels among young adults in June than in April, noting that subjects with higher temperature levels showed similar seasonal variations (26). Each of the above studies noted significant seasonal variability in body temperature parameters, there was an overall lack of agreement from study to study in temperatures of the nature of the variability. Additional research is warranted to better categorize in seasonal rhythm of body temperature and to clarify existing contradictions (16).

SURVIVAL AND TEMPERATURE (12)

- The rate enzymatic activity varies with temperature, increasing for about 2.5 folds for each 10°C rise. However, at temperatures of above than 45°C, the enzymes that catalyze living reactions become denatured.
- Conscious intelligence requires a narrow range of approximately 35 - 40°C.
- Body temperature above 40°C causes heat stroke, mental confusion and unconsciousness.
- Temperature below 34°C gives rise to amnesia and also to unconsciousness.
- Cardiac temperature below 30°C causes arrhythmias and then cardiac arrest. However, if the circulation is supported, the heart can survive for a period of time and function well after rewarming.
- The whole body can be cooled to 10°C with consequently no circulation with yet high probability of unimpaired survival after rewarming.
- Cooling of the individual organs and tissues is used to permit survival in the absence of circulation.
- Cooling is also used in neurosurgery to avoid bleeding and extensive tissue damage.

THERMOMETERS

Thermometers, which are instruments for measuring body temperature calibrated in either degrees Fahrenheit (°F) or degrees Celsius (°C), depending on the custom of the region. Thermometers in the USA are often measured in degrees Fahrenheit, but the standard in most other countries in degrees Centigrade (°C). The equations of converting Centigrade and Fahrenheit scales and corresponding Centigrade measurements for common reported Fahrenheit temperatures are as follows (4):

$$C = 5/9\ ({}^{o}F - 32);\ F = (9/5 \times {}^{o}C) + 32;\ \text{e.g. } 40^{o}C = 104^{o}F,\ 37^{o}C = 98.6^{o}F,\ \text{and } 35^{o}C = 95^{o}F.$$

MATERIALS AND METHODS

MATERIALS

Ethical clearance & informed consent of national and respondents were obtained. The study design was a descriptive cross sectional with stratified randomized sampling. A total number of 235 respondents of both sexes and age ranging from 18 – 50 years of 235 apparently normal fit Sudanese. Glass thermometer used for its safety and easy use; cotton and disinfectants were used; a technician and a volunteer helped in data collection and analysis.

METHODOLOGY

Because of study nature that focusing on diurnal variation in body temperature, two temperature readings (07:00 – 09:00 AM & 19:00 – 21:00 PM) were taken from armies, holy Quraan students, and Alfashir University students. The questionnaire included personal data (name, sex, age, serial number, and address), a question whether subjects contracted one of the febrile diseases (malaria, tonsillitis, stomatitis, chest and wound infections, food poisoning, urinary tract and diarrheal diseases as well as any acute state that tends to raise body temperature) within the last week. Also people were asked whether smoked, chewed gum, ingested hot or cold liquid within the previous 30 minutes. Finally, the researcher asked female respondents about the onset of their menstrual cycles in order to exclude those who were at ovulating time. Oral method which is the most common way of taking a temperature (4); advisedat least 20 – 30 minutes waited after smoking, eating, or drinking a hot or cold liquid before taking a temperature; if vigorous exercise or a hot bath were performed, the temperature measurements should be taken after an hour. The sequential procedures were made as: taking the thermometer out of its holder and held by the end opposite the colored (red, blue) tip; cleaning the thermometer with powder soap and warm water; thermometer was turned in a hand and checked well until it read less than 96^{o}F; with opened mouth, the end with red & blue putted under the tongue and lips were closed gently around the thermometer without biting the glass; the thermometer then removed without touching its tip & held at eye level with slowly turning it until silver-coated long mark on the thermometer seen; finally, again the thermometer washed with soap and warm water.

DATA ANALYSIS METHOD

The obtained data were statistically analyzed by using statistical package for social science programme (SPSS). Software statistical analysis (T-test) was performed considering mean body temperature and its diurnal variation as dependent variables; whereas sex, age, and time of temperature measurement were considered independent variables. The data were represented as mean ±1SD. The relation between mean body temperature and variables was considered significant only when probability equals or less than 0.05 ($P \leq 0.05$).

RESULTS AND DISCUSSION

MEAN ORAL TEMPERATURE OF NORMAL SUBJECTS

In this study, the mean oral temperature among the normal adults was 36.47^{o}C, with standard deviation of 0.35^{o}C, and mean diurnal variation of 0.94 ± 0.61^{o}C as shown in (**Table 1**).

Table 1: ***Mean oral temperature & diurnal variation, their standard deviations in normals***

Mean (X)			Diurnal variation
Morning	**Evening**	**Whole day**	
36.00 ± 0.55^{o}C	36.94 ± 0.37^{o}C	36.47 ± 0.35^{o}C	0.94 ± 0.61^{o}C

The relation between mean oral temperature and its diurnal variation was calculated from the preceding readings of body temperature in both January and February among the normal subjects as in (**Table 2**).

Table 2: ***Month variation between mean oral temperature and its diurnal change (normal subjects)***

Group	Mean (X)	Diurnal variation
Subjects of January	36.43°C	0.99°C
Total subjects (235)	36.47°C	0.94°C
Subjects of February	36.79°C	0.53°C

MEAN ORAL TEMPERATURE AND SEX IN NORMAL SUBJECTS

The probability of correlation (P) between the mean oral temperature and sex was 0.01. Statistically temperature was related strongly to sex as shown in (**Figure 1**).

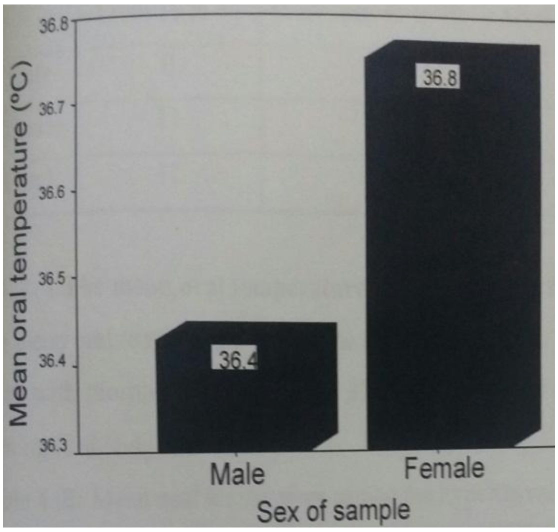

Figure1: Mean oral temperature in males and females of normal subjects (36.4°C for males with 36.8°C for females)

MEAN ORAL TEMPERATURE AND AGE IN NORMAL SUBJECTS

Statistically, strong relation was shown between mean oral temperature and age (P = 0.01). Elderly people had a temperature magnitude less than young adults (negative sign of correlation coefficient).

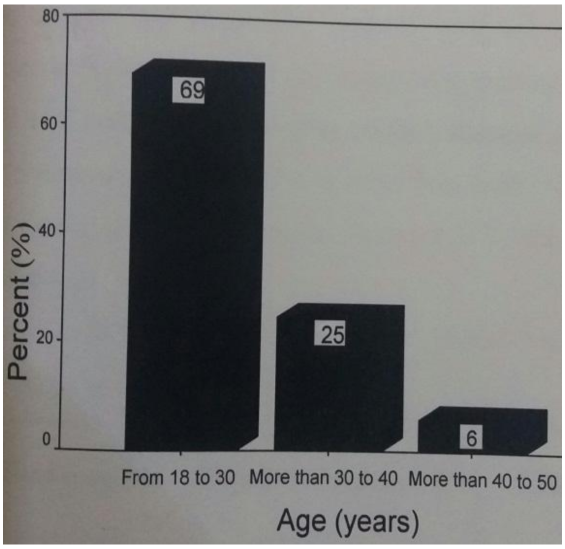

Figure 2: Effect of age on mean oral temperature in normal subjects

MEAN ORAL TEMPERATURE ANDMEASURING-TIMEINNORMALS (January = Jan, and February = Feb)

The relation between mean oral temperature and its diurnal variation was calculated from the preceding readings of body temperature in both January and February among the normal subjects as in (**Table 3**).

Table 3: ***Season, mean oral temperature, & diurnal variation with standard deviations in normals***

Time/ Reading	Number of Subjects (N)		Mean (X)		Standard deviation (SD)	
	Jan	Feb	Jan	Feb	Jan	Feb
Morning	205	30	35.93°C	36.52°C	0.53	0.37
Evening	205	30	36.92°C	37.05°C	0.37	0.38
Circadian rhythm	205	30	0.99°C	0.53°C	0.60	0.50
Morning + Evening	205	30	36.43°C	36.79°C	0.34	0.28

The experiment showed mean temperature and diurnal values among normal subjects as 36.47 ± 0.35°C; and 0.94 ± 0.61°C respectively. The results reflected lower mean oral temperature than other studies in normal people 36.67 – 36.94°C & 36.81°C, 37°C, 36.8°C, and 36.86°C by(9); (10); (7); (8)respectively; higher than 36.15°C (11); while agrees with maximum value 36.94°C by (9). Diurnal results in our normals were higher than values 0.5 – 0.7°C, 0.6°C, 0.3 – 0.8°C; but, close & lower than 1 – 2°C conducted by (10);(9); (11); (15) respectively. The study also showed higher body temperatures in females than males of normal people for their body fat contain, this goes with studies (8); and (19)in contrast to other studies lacking the effect as (18). Age showed statistical negative effect in our study of normal subjects indicating temperature decrease in elderly for resetting of thermoregulatory centre, decrease muscular activity, and enzymatic system. Our obtained temperature in February, i.e. 36.79^{o}C (close to summer) was higher than that we recorded in January (close to December, winter), i.e. 36.43^{o}C. Therefore, our data indicate a relation between season of the year and body temperature (**Table 2 & Table 3**) as found also in studies conducted by (24) and (25).

CONCLUSION

In our research work, the obtained mean oral and diurnal temperatures among normal individuals were 36.47 ± 0.35^{o}C; and 0.94 ± 0.61^{o}C respectively. A magnitude of body temperature reversely related to diurnal variation magnitude, i.e. low diurnal variation with high body temperature and vice versa as in (Table 2 & Table 3). Gender, age, and season affect normal body temperature in normal individuals. Diurnal body temperature normality indicates alertness of brain biologic “clocks” controlling it, so worth noting to raise the awareness of medical professionals and publics about the necessity of measuring this parameter

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