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THE CIRCADIAN RHYTHM OF CORE BODY TEMPERATURE (PART I): THE USE OF MODERN TELEMETRY SYSTEMS TO MONITOR CORE BODY TEMPERATURE VARIABILITY

Joanna Słomko, Paweł Zalewski

Department of Hygiene, Epidemiology and Ergonomics, CM UMK in Bydgoszcz, Poland

ABSTRACT

The best known daily rhythms in humans include: the sleep-wake rhythm, the circadian core body temperature variability, daily fluctuations in arterial blood pressure and heartbeat frequency, and daily changes in hormone secretion: e.g. melatonin, cortisol, growth hormone, prolactin. The core body temperature in humans has a characteristic sinusoidal course, with the maximum value occurring between 3:00-5:00 pm and the minimum between 3:00-5:00 am. Analysis of literature indicates that the obtained results concerning core body temperature are to a large extent influenced by the type of method applied in the measurement. Depending on test protocols, we may apply various methodologies to measuring core body temperature. One of the newest methods of measuring internal and external body temperature consists in the utilisation of remote temperature sensors transmitting the obtained value via a radio signal. The advantages of this method includes the ability to perform: continuous core temperature measurement, observe dynamic changes in core body temperature occurring in circadian rhythm and the repeatability and credibility of the obtained results, which is presented in numerous scientific reports.
Key words: body temperature, circadian rhythms, telemetric measurement.

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THE CIRCADIAN RHYTHM OF CORE BODY TEMPERATURE

The circadian rhythm constitutes the condition for the proper functioning of an organism. It enables the adjustment of numerous internal processes to cyclically changing environmental conditions resulting from the rotational motion of the Earth. The best known daily rhythms in humans include: the sleep-wake rhythm, the circadian core body temperature variability, daily fluctuations in arterial blood pressure and heartbeat frequency, and daily changes in hormone secretion: e.g. melatonin, cortisol, growth hormone, prolactin [1].

Core body temperature in humans has a characteristic sinusoidal course, with the maximum value occurring between 3:00-5:00 pm and the minimum between 3:00-5:00 am. The deviation between the highest and the lowest temperature within a 24-hour period can reach as much as 1°C. Temperature fluctuations are strictly connected with the functioning of the autonomous nervous system, and is an expression of the circadian changeability in the metabolism of thermal production and loss (Tab. 1).

Core body temperature decreases at night when the mechanisms of temperature loss from the organism predominate. Moreover, the key role in core body temperature regulation at night, during sleep, is played by melatonin secretion, which, by acting on the hypothalamic thermoregulatory centre, has an immediate impact on its reduction.

Tab. 1.

The mechanisms of temperature production and loss from an organism.

Temperature production in an organism	Temperature loss from an organism
- primary metabolic processes, - increased muscle activity, - active hormonal impact (e.g. thyroid), - increased metabolic activity as a result of activity of sympathetic system, - increased metabolic activity due to food digestion.	- radiation (electromagnetic radiation emission within the infrared scope of 5-20 μm), - conduction (conduction of thermal energy to the ambient air and objects remaining in contact with skin surface), - convection (forced movement of separated thermal energy as a result of air currents of the ambient environment acting on skin surface), - evaporation (thermal loss through heating and evaporation of water secreted by sweat glands of the skin).

Particular attention should be paid to the effect of environmental factors (sleep deficiency, meal consumption, physical activity) on thermoregulatory processes, which are largely subject to autonomous control through, among other things, blood flow regulation and sweat glands innervation. Hence, numerous authors present in their works multiple relationships between core body temperature and the autonomous nervous system [2-6].

DISTURBANCES IN THE CIRCADIAN CORE BODY TEMPERATURE RHYTHM

The existence of a biological clock, and its significant role in maintaining homoeostasis in the organism, allows one to assume that disturbances in its functioning may have negative consequences for the human organism.

The available literature lacks works that evaluate cyclic and continuous changes in core body temperature, with the most commonly applied measurement method being rectal measurement. Launay et al. have shown that sleep deprivation causes a significant increase in the minimal temperature values from 36.1°C before the experiment to 36.5°C following 62 hours of lack of sleep [7].

Similar results, obtained by Murray et al. reveal that during a 98-hour period of sleep deprivation core body temperature preserves its sinusoidal course with an accompanying gradual decrease in the amplitude [8]. According to Vaara et al. the reason for this phenomenon may rest in the direct effect of sleep deprivation on a reduced activity of brain centres, including the hypothalamus, causing disturbances in the circadian rhythm of core body temperature [9].

Multiple studies describe the effect of shift work

on disturbances in the circadian rhythm of core body temperature. People with an intolerance of the shift work system show a decrease in the amplitude of circadian fluctuations of core body temperatures, a shift of the circadian maximum and an occurrence of free-running rhythms, i.e. with a frequency other than 24 hours [10,11].

THE USE OF MODERN TELEMETRY SYSTEMS TO MONITOR CORE BODY TEMPERATURE VARIABILITY

The analysis of literature indicates that the obtained results concerning core body temperature are to a large extent influenced by the type of method applied in its measurement. Depending on test protocols, there are various methods of performing core body temperature measurements.

Many researchers indicate blood temperature measured in the pulmonary artery to be the location which provides the truest representation of core body temperature. The most common method of temperature measurement, due to its availability, consists in the measurement performed in the axilla and with the use of an infrared sensor placed near the tympanic membrane.

An important drawback to these methods of measurement consists in the fact that the temperature value if the tympanic membrane and the axilla often reveals quite a significant diversification on both sides and between consecutive measurements. One of the newest methods of measuring internal and external body temperature consists in the utilisation of remote temperature sensors transmitting the obtained values via a radio signal. The use of a telemetric capsule and a dermal sensor dates back to 1968.

The dynamic development of electronic technologies has led to the working out of an easily available non-invasive and extremely reliable method of temperature measurement [12]. The Vital Sense system by *Mini Mitter*, currently *Philips Respironics* (*Vital Sense, Mini Mitter Co. Inc., Bend Oregon, USA*), is an attested device used for remote measurement of internal and external body temperature.

The system comprises two components: a mobile recording monitor, storing and exporting digital data of the measured temperature values, and a telemetric capsule – *Core Body Temperature Capsule (CBTC)*. The telemetric capsule transmits the measured core body temperature values in the form of a radio signal.

The examined person swallows the capsule with a small amount of warm water, after approximately one minute, the capsule commences internal body temperature measurement and emits radio signals at 15-second intervals, with the average value from four consecutive measurements recorded in the monitor's memory.

The telemetric capsule is resistant to the activity of digestive enzymes and is excreted from the subject's organism with no side effects or impact on the functions of the gastrointestinal tract [13,14].

The advantages of this method include: the possibility to obtain continuous core body temperature measurements (Fig. 1), observation of dynamic changes in core body temperature occurring in circadian rhythm, and the repeatability and credibility of the obtained results, which is presented in numerous scientific reports [15].

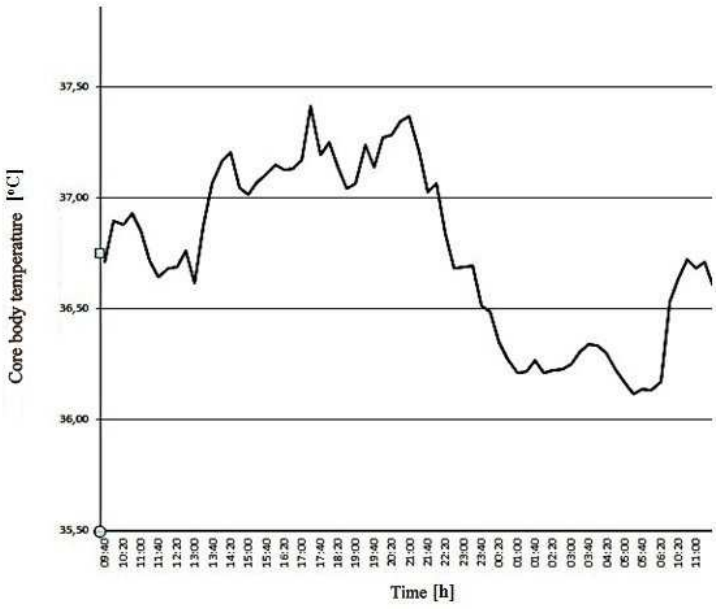

Fig. 1. Chart representing variations in the circadian core body temperature rhythm.

Moreover, research results indicate that the correlation between core body temperature measurements with the use of the Vital Sense system, and blood temperature in the pulmonary artery (recognised as the correct location in which to measure the temperature of the interior of the body), is very strong and reaches r=0.96 (p<0.0001) [16].

Summarising, the use of modern telemetric systems enables credible and continuous evaluation of core body temperature, which is of a great significance for chronobiological studies.

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Joanna Słomko
Department of Hygiene, Epidemiology and Ergonomics,
CM UMK in Bydgoszcz ul. M. Sklodowskiej-Curie 9
85-094 Bydgoszcz, Poland
e-mail: jslomko@cm.umk.pl