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(ISO 9886:1992)

Evaluation of thermal strain by physiological measurements
(ISO 9886:1992)

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English version

Evaluation of thermal strain by physiological measurements (ISO 9886:1992)

Evaluation de l'astreinte thermique par mesures physiologiques (ISO 9886:1992)

Ermittlung der thermischen Beanspruchung durch physiologische Messungen (ISO 9886:1992)

This European Standard was approved by CEN on 19 January 2001.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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Foreword

The text of the International Standard from Technical Committee ISO/TC 159 "Ergonomics" of the International Organization for Standardization (ISO) has been taken over as an European Standard by Technical Committee CEN/TC 122 "Ergonomics", the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by October 2001, and conflicting national standards shall be withdrawn at the latest by October 2001.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Endorsement notice

The text of the International Standard ISO 9886:1992 has been approved by CEN as a European Standard without any modification.

Introduction

This International Standard is part of a series of standards concerned with the assessment of thermal stress and strain.

This series of International Standards aims in particular at:

a) establishing specifications for the methods of measuring physical parameters characterizing thermal environments;

b) establishing methods for assessing thermal stress in cold, moderate and hot environments.

The analysis methods described by these latter standards allow the prediction of the average physiological response of subjects exposed to a thermal environment. Some of these methods are not applicable under exceptional climatic circumstances, when the characteristics of the exposed subjects differ greatly from the average or when special means of protection are used.

In these cases, or for the sake of research, it may be useful or even necessary to measure directly the physiological strain experienced by the subject.

This International Standard gives a series of specifications concerning the methods of measurement and interpretation of the physiological parameters considered as reflecting the response of the human organism placed in a hot or cold environment.

Evaluation of thermal strain by physiological measurements

1 Scope

This International Standard describes methods for measuring and interpreting the following physiological parameters:

a) body core temperature;

b) skin temperatures;

c) heart rate;

d) body mass loss.

The choice of variables to be measured and techniques to be used is at the discretion of those responsible for the health of the employees. These persons will have to take into account not only the nature of the thermal conditions, but also the degree of acceptance of these techniques by the employees concerned.

It should be emphasized that direct measurements on the individual may only be carried out on two conditions:

a) if the person has been fully informed about the discomfort and the potential risks associated with the measurement technique and gives free consent to such measurements;

b) if the measurements present no risk for the person which is unacceptable in view of general or specific codes of ethics.

In order to simplify this choice, annex A presents a comparison of the different methods concerning their field of application, their technical complexity, the discomfort and the risks that they might involve.

This International Standard defines the conditions which are to be met in order to ensure the accuracy of the data gathered from the different methods. The measurement methods are described in annex B. Limit values are proposed in annex C.

This International Standard is not concerned with experimental conditions for which investigators may develop alternative methods intended to improve knowledge in this area. It is recommended, however, when conducting such studies in the laboratory, to use the methods described below as references, so that results can be compared.

2 Measurement of body core temperature, t_{cr}

2.1 General

The term "core" refers to all the tissues located at a sufficient depth not to be affected by a temperature gradient through surface tissue. Temperature differences are however possible within the core depending on local metabolisms, on the concentration of vascular networks and on local variations in blood flow. The core temperature is thus not a unique concept and measurable as such. This temperature may be approximated by the measurement of temperature at different points of the body:

a) oesophagus: oesophageal temperature, t_{es};

b) rectum: rectal temperature, t_{re};

c) gastro-intestinal tract: intra-abdominal temperature, t_{ab};

d) mouth: oral temperature, t_{or};

e) tympanum: tympanic temperature, t_{ty};

f) auditory canal: auditory canal temperature, t_{ac};

g) urine temperature, t_{ur}.

The order of presentation of these different techniques has been adopted only for the clarity of the presentation.

Depending on the technique used, the temperature measured can reflect

— the mean temperature of the body mass; or

— the temperature of the blood irrigating the brain and therefore influencing the thermoregulation centres in the hypothalamus. This temperature is usually considered for assessing the thermal strain sustained by a subject.

2.2 Measurement techniques for indicators of body core temperature

2.2.1 Oesophageal temperature, t_{es}

2.2.1.1 Principle of the method

The temperature transducer is introduced in the lower part of the oesophagus, which is in contact over a length of 50 mm to 70 mm with the front of the left auricle and with the rear surface of the descending aorta. In this position, the temperature transducer registers variations in arterial blood temperature with a very short reaction time.

The upper part of the oesophagus presses against the trachea and the measurement of temperature at that level is affected by breathing. On the contrary, if the transducer is placed too low, it records gastric temperature.

The transducer is also influenced by the temperature of the saliva swallowed by the subject. The oesophageal temperature is therefore not given by the mean value of the recorded temperatures but by the peak values. This is particularly true in cold environments, where the saliva can be chilled.

2.2.1.2 Interpretation

Of all the indirect measurements of t_{cr} mentioned above, t_{es} is the one which most accurately reflects temperature variations in the blood leaving the heart, and in all probability, the temperature of the blood irrigating the thermoregulation centres in the hypothalamus.

2.2.2 Rectal temperature, t_{re}

2.2.2.1 Principle of the method

A temperature transducer is inserted in the rectum; this being surrounded by a large mass of abdominal tissues with low thermal conductivity, the rectal temperature is independent of ambient conditions.

2.2.2.2 Interpretation

When the subject is resting, the rectal temperature is the highest of the body temperatures. When the subject is working, on the contrary, t_{re} is directly affected by the production of heat from the local muscles: with an equal expenditure of energy per unit of time, t_{re} is higher when work is performed with the legs than when it is carried out exclusively with the arms.

t_{re} essentially gives an indication of the mean temperature of body core mass. It may only be considered as an indicator of blood temperature and therefore of the temperature of the thermoregulation centres when heat storage is slow and when work is performed using the whole body.

When heat storage is low and work is essentially performed with the legs, the measurement of t_{re} leads to a slight overestimation of the temperature of the thermoregulation centres. On the contrary, in case of rapid storage, during intense thermal stress of short duration, t_{re} rises at a slower rate than the temperature of the thermoregulation centres, continues to rise after the exposure has stopped and finally decreases progressively. Rising speed and lag time are depending on the exposure and recovery conditions. In theses cases t_{re} is an inappropriate way in which to estimate the strain sustained by a subject.

2.2.3 Intra-abdominal temperature, t_{ab}

2.2.3.1 Principle of the method

A temperature transducer is swallowed by the subject. During its transit through the intestinal tract, the temperature recorded will vary according to whether it is located in an area close to large arterial vessels or to organs with high local metabolism or, on the contrary, near the abdominal walls.

2.2.3.2 Interpretation

When the transducer is located in the stomach or the duodenum, temperature variations are similar to those of t_{es} and the difference between the two temperatures is very small. As the transducer progresses inside the intestine, the characteristics of the temperature come closer to those of t_{re}. Therefore, the interpretation will depend on the time elapsed since the swallowing of the transducer and on the speed of the gastro-intestinal transit for the given subject.

In the present state of knowledge, t_{ab} seems to be independent of ambient climatic conditions, except for strong radiant heat impinging on the abdomen.

2.2.4 Oral temperature, t_{or}

2.2.4.1 Principle of the method

The transducer is placed underneath the tongue and is therefore in close contact with the deep arterial branches of the lingual artery. It will then provide a satisfactory measurement of the temperature of the blood influencing the thermoregulation centres.

The temperature measured nevertheless, depends on the external conditions. When the mouth is open,

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thermal exchanges by convection and evaporation on the surface of the buccal mucus membrane contributes to a reduction in the temperature of the buccal cavity. Even when the mouth is closed, the temperature can be significantly lowered as a function of a reduction in the cutaneous temperature of the face, or raised if the face is exposed to strong radiant heat.

2.2.4.2 Interpretation

When the measurement conditions are met, t_{or} is very similar to t_{es}. With the subject resting and in environments in which air temperature is greater than 40 °C, t_{or} can overestimate t_{es} by 0,25 °C to 0,4 °C. With the subject working, the concordance between t_{or} and t_{es} is only established for muscular effort levels not exceeding 35 % of the maximal aerobic power of the subject.

2.2.5 Tympanic temperature, t_{ty}

2.2.5.1 Principle of the method

The thermal transducer is placed as close as possible to the tympanic membrane whose vascularisation is provided in part by the internal carotid artery which also irrigates the hypothalamus. As the thermal inertia of the eardrum is very low, due to its low mass and high vascularity, its temperature reflects the variations in arterial blood temperature which influence the centres of thermoregulation.

However, as the tympanic membrane is also vascularised by the external carotid aretery, its temperature is influenced by the local thermal exchanges existing in the area vascularised by this artery.

2.2.5.2 Interpretation

t_{ty} varies in a similar fashion to t_{es} during rapid variations in the thermal content of the core, whether these are of metabolic origin or caused by the environment. The observed difference between these two temperatures or between t_{ty} and t_{re} is however influenced by local heat exchanges around the ear and the cutaneous surface of the head.

2.2.6 Auditory canal temperature, t_{ac}

2.2.6.1 Principle of the method

The transducer is, in this case, located against the walls of the auditory meatus immediately adjacent to the tympanum. These are vascularised by the external carotid artery and their temperature is affected both by the arterial blood temperature at the heart and by the cutaneous blood flow around the ear and adjacent parts of the head. A temperature gradient is thus observed between the tympanum and the external orifice of the auditory meatus. This gradient can be reduced by insulating the ear adequately from the external climate.

2.2.6.2 Interpretation

The interpretation principles are very similar to those presented for the tympanic temperature. The auditory canal temperature therefore undergoes variations parallel to those of t_{es}, in the same way as t_{ty}.

However, the positive deviations in hot environments or the negative ones in cold climates from t_{es} are systematically greater than for t_{ty}. Therefore, t_{ac} may rather be considered as an indicator of the combined temperatures of the core and of the skin, than of an indicator of the core temperature only.

This temperature measuring site is accepted by some as a necessary compromise between the precision of the estimation and the practicability for the subject and the observer.

2.2.7 Urine temperature, t_{ur}

2.2.7.1 Principle of the method

The bladder and its content may be considered as being part of the core of the body. Therefore, the measurement of the urine temperature during its discharge can provide information concerning the body core temperature t_{cr}. The measurement is made by means of a temperature transducer inserted in a collecting device. By definition, the measurement possibilities are dependent on the quantity of urine available in the bladder.

2.2.7.2 Interpretation

Urine temperature varies approximately as t_{re}, except the time constant is somewhat greater and its actual value is systematically lower than t_{re} by 0,2 °C to 0,5 °C.

3 Skin temperature, t_{sk}

3.1 General

Skin temperature varies widely over the surface of the body and especially when the ambient conditions are cold. For this reason, a distinction should be made between

— the local skin temperature, t_{sk}, measured at a specific point of the body surface

— the mean skin temperature, $\overline{t_{sk}}$, on the entire surface of the body, which cannot be easily measured directly but can be estimated by