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Respiratory protective devices — Human factors —

Part 6: Psycho-physiological effects

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 94, Personal safety — Protective clothing and equipment, Subcommittee SC 15, Respiratory protective devices.

This first edition of ISO 16976-6 cancels and replaces the second edition of the Technical Specification ISO/TS 16976-6:2014, which has been technically revised.

The main changes are as follows:

— the document has been editorially revised.

A list of all parts in the ISO 16976 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document addresses the psychological factors that can trigger physiological effects (psycho-physiology effects) that contribute to user acceptance, or the ability to tolerate wearing respiratory protective devices (RPD) for the duration needed. This document takes the position that the psychological state has a physiological correlate (e.g. anxiety is accompanied by an increase in heart rate) and that the physiological responses to wearing an RPD have an impact on the psychology of the wearer (e.g. difficulty in breathing will result in anxiety). The following clauses focus on a separate psycho-physiological situation that can impact user acceptance or contribute to the likelihood of the wearer removing the RPD prematurely and, thus, being exposed to a respiratory hazard. The physiological responses to wearing an RPD is addressed first followed by a discussion on the psychological responses to wearing RPD. The discussion then turns to the methodologies used to measure the psycho-physiological responses and how these measurements are used to predict whether an individual will have difficulty wearing an RPD. Finally, this document addresses the selection criteria that can be used to determine who is best suited to engage in an occupation requiring the use of RPD.

Respiratory protective devices — Human factors —

Part 6:
Psycho-physiological effects

1 Scope

This document provides information on the psycho-physiological effects related to the wearing of respiratory protective devices (RPD) and it is intended for the preparation of standards for selection and use of RPD.

It specifies for the writers of RPD standards, principles relating to

— the interaction between RPD and the human physiological and psychological perception,

— the acceptance by the wearer, and

— the need for training to improve acceptance of the RPD by the wearer.

This document does not cover requirements related to the specific hazard for which the RPD is designed.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 16972, *Respiratory protective devices — Vocabulary and graphical symbols*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 16972 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
aetiopathology
cause of the pathological state or disorder, pathogenesis

3.2
anxiety
state of being uneasy, apprehensive, or worried about what might happen, misgiving

3.3
blood pressure
BP
pressure in the large arteries of the body, typically measured in the bracheal artery

3.4
cardiac arrhythmia
variation from the normal rhythm of the heart beat

3.5
claustrophobia
abnormal fear or dread of being in an enclosed or confined space

3.6
dysphoria
sensation of disquiet, restlessness, or malaise

3.7
dyspnoea
sense of air hunger, difficult or laboured breathing, or a sense of breathlessness

3.8
heart rate
HR
number of times the heart beats in 1 min

3.9
hypercapnia
excess amount of CO_2 in the blood

3.10
hyperventilation
increase in overall respiration resulting from an increase in both the depth and frequency of breathing

Note 1 to entry: This can be voluntary or result from an increase in activity, fear, or breathing excess carbon dioxide (CO_2).

3.11
hypoxia
volume fraction or partial pressure of oxygen in the breathing atmosphere below that found in the atmosphere at sea level

3.12
metabolism
metabolic rate
energy produced in human cells by aerobic or anaerobic processes

3.13
minute ventilation
$\dot{V}_E$
total volume of air inspired (or expired) in the lungs during 1 min, in $l \cdot min^{-1}$ (BTPS)

3.14
paresthesia
abnormal sensation without objective cause such as numbness, prickling, and tingling; heightened sensitivity

3.15
psycho-physiological effect
psychological trait(s) and responses to a given situation which can provoke a physiological response and the physiological responses to a given situation which can provoke a psychological reaction

3.16
respiratory rate
RR
number of breaths taken in 1 min

3.17
SaO_2
degree of saturation of haemoglobin with oxygen in arterial blood

Note 1 to entry: Expressed as a percentage of total saturation.

3.18
stereoacuity
visual clarity in three dimensions

3.19
tachycardia
increased heart rate due to exercise, pain, *anxiety* (3.2), or pathophysiological state

3.20
$tcCO_2$
measured transcutaneous carbon dioxide

Note 1 to entry: The level of carbon dioxide in tissue vasculature, as measured by a transcutaneous CO_2 detector attached to the earlobe.

3.21
phobia
any persistent and irrational fear of a specific object, activity, or situation that results in a compelling desire to avoid the feared stimulus

3.22
state-trait anxiety inventory
STAI
psychological assessment tool used to determine the presence and type of *anxiety* (3.2) in an individual and is used to differentiate between situational *anxiety* (3.2) (state anxiety) and chronic feelings of *anxiety* (3.2) as part of the overall personality structure (trait anxiety)

4 Symbols and abbreviated terms

BP	blood pressure
FFR	filtering facepiece respirator
HR	heart rate
IDLH	immediately dangerous to life and health
Pa	Pascal
RPD	respiratory protective device
RR	respiratory rate
SA	state anxiety
SaO_2	arterial oxyhaemoglobin saturation
SARS	severe acute respiratory syndrome
SCBA	self-contained breathing apparatus
STAI	state-trait anxiety inventory
TA	trait anxiety

T_{sk}	skin temperature
$\dot{V}_E$	minute ventilation
VO_2	rate of oxygen consumption during breathing
VCO_2	rate of carbon dioxide production during breathing
WoB	work of breathing

5 Psycho-physiological effects influencing user acceptance of RPD

5.1 General

Many occupations require workers to wear RPD to protect them from hazardous atmospheres. However, a small but significant fraction of the workers find it difficult or even impossible to wear RPD for longer than a few minutes. This might be due to the physical discomfort of a poorly fitting RPD or due to dangerous situations under extreme circumstances or might be due to the particular psychological traits of the wearer's personality. Wearing an RPD provokes physiological responses in essentially all wearers and it appears to be the psychological response to the physiological sensations (air hunger, heat, narrowing of the visual field) that might provoke a psychological reaction that renders the individual incapable of wearing the RPD. The following sections address first the physiological responses to wearing RPD and the potential psychological reactions to those physiological responses.

5.2 Physiological responses to wearing RPD and impact on performance of work

5.2.1 General

The simple act of donning an RPD can elicit a number of psychological responses that can be independent of the environment in which the RPD is used. Wearing an RPD can alter the concentration of oxygen (O_2) and carbon dioxide (CO_2) in the breathing space that, if of sufficient magnitude, significantly affect gross respiratory function (e.g. increase or decrease in minute ventilation). In addition, wearing an RPD is associated with changes in cardiovascular function in response to sympathetic nervous system stimulation, reduction in physical performance, work of breathing, changes in $\dot{V}_E$ (e.g. dyspnoea) as a result of increased resistance to airflow, and sensation of heat. In most, if not all people, there will be a psychological response to the physiological sensations that are experienced by the wearer of the RPD. The psychological responses will determine the degree of wearer acceptance of the RPD and compliance with the requirements of RPD necessary in providing an appropriate level of protection. Each of the physiological responses is discussed in the following paragraphs.

5.2.2 Oxygen (O_2) and carbon dioxide (CO_2) in the breathing space

The physiological responses to O_2 and CO_2 in the breathing space have already been addressed in detail in ISO 16976-3 and in a recent review article[63]. Briefly, changes in the concentration of either O_2 or CO_2 in the breathing space might significantly alter the cardiorespiratory system as evidenced by changes in heart rate (HR), blood pressure (BP), $\dot{V}_E$, blood pH, and other physiological parameters. Reduced atmospheric O_2 (hypoxia) results in an increased ventilatory response[11] and increased cardiac output due to stimulation of the central nervous system[14] in order to ensure adequate oxygenation of the blood and elimination of metabolically produced CO_2. Severe hypoxia results in a constellation of signs and symptoms including a decrease in exercise tolerance, a decrease in cold tolerance, dizziness, euphoria, loss of consciousness, and if oxygen is not administered quickly, death from asphyxiation[33]. Mild hypoxia results in little change in the healthy person[12] and results in an initial mild respiratory depression followed by an increase in $\dot{V}_E$ [14]. Breathing hyperoxic gas mixtures under higher atmospheric pressure (underwater diving, caisson work) can result in generalized

seizures, hallucinations, involuntary movements, paresthesias, psychological changes (dysphoria, amnesia), and problems with some autonomic (involuntary) nervous system function[56].

Breathing elevated CO_2 might result in changes in stereoacuity and perception of coherent motion[57] [65] reduced retinal blood flow[32] increased rate of body heat loss during snow burial[16] decreased performance on reasoning tasks, subjective increases in both irritability and discomfort[46], and reduced ability to exercise during simulated emergency escape procedures[7], an increase in resting $\dot{V}_E$ of up to 75 l·min^{-1}[50], induction of anaesthesia, as well as inert gas narcosis[33]. Increased partial pressure of CO_2 (PCO_2) affects pulmonary $\dot{V}_E$ disproportionate to the level of exercise, thus, increasing the metabolic cost of breathing as well as inducing a sense of "air hunger" (dyspnoea) that limits exercise tolerance[7] and can increase the potential to induce cardiac arrhythmias[33].

For some workers, the RPD does not seem to present a significant problem during relatively short-term use[43]. Roberge et al.[45] found that O_2 and CO_2 in the breathing space remained relatively unchanged but retention of CO_2 (increased $tcCO_2$) occurred after about one hour of wear. This level of $tcCO_2$ did not result in symptomatology but might be a cause for concern if the worker wore the RPD for longer than an hour. It is interesting to note that there were small but statistically significant differences in SaO_2 between filtering facepiece respirator (FFR) RPD with and without an exhalation valve.

5.2.3 Metabolic rate during RPD use

Wearing an RPD generally results in an increase in the metabolic rate of the wearer over and above the increase resulting from performing physical work alone. Clinically significant increases in metabolic rate as measured by increased HR, BP, RR, and elevated skin temperature, T_{sk}, in the immediate proximity underneath the RPD have been noted at moderate and higher workloads and attributable to increased breathing resistance of the FFR[22]. In other studies in which ventilator resistance was varied, exercise tolerance to increased breathing resistance decreased[18]. These general physiological responses were also noted by Smith et al.[51] Raven et al.[41] noted a 17 % to 21 % decrement in function, a 37 % increase metabolic rate, a 24 % increase in BP, and a 27 % increase in submaximal HR. Increased breathing resistance in RPD also resulted in a decrease in O_2 uptake leading to increased O_2 deficiency during exercise, and a decrease in $\dot{V}_E$ [41] In studies by White et al.[63], subjects wearing protective clothing including RPD also experienced an increased physiological burden as manifested by increased HR and decreased work tolerance that worsened at higher work intensities. The increased HR and RR have also been measured in subjects wearing FFR[26]. These responses are a clear indicator of an increase in the physiological cost of wearing respirators and the greater resistance to air flow, the greater the workload and the greater the physiological effect.

5.3 Subjective feelings of discomfort

5.3.1 General

A commonly reported type of discomfort related to wearing RPD is headache. In a report by Lim et al.[29], 37,3 % of respondents reported headache associated with wearing FFR during an epidemic of severe acute respiratory syndrome (SARS) in Asia and Canada that required analgesic medication and sick leave. Although some respondents reported that they had chronic headache that was exacerbated by RPD use, others reported that the use of the RPD alone caused headache. Lim et al.[30] suggested that the aetiopathology could be hypoxemia, hypercapnia, mechanical factors (e.g. poor-fitting respirator), or stress associated with the circumstances of use (dangerous epidemic). However, neither the gas concentrations in the breathing space of the RPD nor blood gases were measured. Therefore, it is difficult to determine the specific cause of RPD-associated headache in this study. Others have suggested that excessive pressure on superficial nerves in the head, poor RPD fit, or pulling FFR straps too tightly might be the root cause of the headaches[29].

Reports of headache during and after RPD use might also be due to exposure to an elevated level of CO_2 in the breathing environment. A report by NIOSH[3] summarized 19 studies on the effects of CO_2 on human subjects. Both the physiological responses to acute and longer term exposure were described. The results of these studies have been integrated into ISO 16976-3. In this summary, studies supported