

USABILITY OF ISO THERMAL STANDARDS FOR COLD RISK ASSESSMENT IN THE WORKPLACE

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ABSTRACT

In this study the usability of ISO thermal standards suitable for cold risk assessment in the workplace was evaluated. Persons who were not earlier familiar with the methods were trained to be able to perform the assessments. The assessments were conducted at two different stages according to method complexity, duration and need for expertise. The methods tested at stage 1 included observation and simple measurements (ISO CD 15265, ISO 8996, ISO TR 11079) and were assumed to be relatively simple to use. The methods tested at stage 2 included measurements and quantitative analyses (ISO 7726, ISO 8996, ISO 10551, ISO 9920, ISO 9886, ISO TR 11079). Training to use the methods was provided to the observers and measurers. The assessments at stage 1 were performed by 5 observers repeated on three different occasions with 5 different workers. The measurements (stage 2) were conducted by four persons and repeated four times. A questionnaire concerning the usability of the method tested was filled in after each assessment. The results show that the methods of stage 1 were considered easy to adopt, the duration of the assessment was short (average 30 min), the results were easy to analyse and the amount of training was considered to be adequate. The methods of stage 2 were considered more laborious to perform and the total duration of the assessment was on average 4 h 40 min. Furthermore, the training provided was not considered to be entirely sufficient and additional instructions were frequently asked for, especially when analysing the results. Usable elements were recognised from the ISO thermal standards, which could be used at the more advanced stages of cold risk assessment. (*Int J Circumpolar Health 2002; 61: 142-153*)

Keywords: cold, work, risk assessment, ISO thermal standards, usability, training

A cold environmental temperature at work may cause many adverse effects in man, such as discomfort, increased strain/stress, decreased performance or an increased amount of symptoms of diseases that are either caused or aggravated by cold exposure (4, 5). These effects are reflected on work productivity and quality and may have a negative impact on both the employer and the employee. In addition, adverse performance and health effects are not acceptable when considering work safety regulations.

ISO thermal standards provide guidelines of assessment

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and evaluation for thermal environments (hot, moderate or cold). Although many of the thermal standards are self-contained (can be used independently), in a comprehensive assessment they should be used in conjunction with each other in a complementary way. Many of the methods have originally been developed by experts in their field and their application in workplace assessments is limited. Furthermore, concerning cold environments, there are no systematic instructions on how to use the different standards in a complementary manner in practical workplace assessments. ISO 11399 (12) provides principles and instructions for applying thermal standards but is not specifically designed for the assessment of cold thermal environments. There are also some instructions for the design and evaluation of working practices in indoor cold work (1, 3). However, cold-related problems confronted outdoors deviate markedly from indoor work. At the present a standard proposal is under preparation which aims at describing the methods and practices on how to assess and manage occupational health and performance risks in cold outdoor and indoor work (14).

Malchaire et al. (15) have proposed a strategy for the evaluation and prevention of risks due to work in thermal environments, which is implemented at different levels with regard to method complexity, duration and need for expertise. A similar approach has been adopted for the proposal for the strategy of risk assessment, management and working practice in cold environments (14).

It is important to recognise that in order for the standards to be utilised as instruments for assessing thermal environments at workplaces, they have to be practically orientated and usable. Endusers are at the present becoming involved in standardisation work to an increasing extent and usability of the methods is recognised as an issue to be addressed (16). Furthermore, it is of equal importance to take into account that the persons conducting the assessment need instructions and training to be able to use the methods in an optimal way. Therefore, the aim of the present study was to evaluate the usability of the present ISO thermal standards, as well as to evaluate the need for training of workplace and occupational health and safety personnel in the use of these methods.

MATERIALS AND METHODS

Target industries and occupations

The study was conducted in the Oulu region in northern Finland (65° northern latitude) during winter/spring (March–April) 2000. The target industries of the present study were construction work and seafaring. The assessments were conducted among the following outdoor occupations: carpenter, bricklayer, assistant bricklayer, reinforcing bar placer, mounter of prefabricated units and foreman of channel maintenance (seafaring).

Design of the study

The assessments were conducted at two different stages with regard to duration, complexity and degree of analysis. A corresponding classification can be found in a general strategy for assessing risks of thermal environments (15). Methods tested at the first stage were assumed to be relatively simple to perform and analyse. The methods tested at the second stage were assumed to require more analysing and to involve some measurements.

Observers and measurers

The persons conducting the observations and measurements were not previously familiar with the methods. A total of 5 observers conducted the observations (stage 1). These persons were three occupational nurses, one safety delegate (workers representative) from the construction industry and one research assistant from Oulu Regional Institute of Occupational Health. The persons performing the measurements (stage 2) were educated and oriented to occupational health and safety. These consisted of two occupational nurses, one researcher and one research assistant from Oulu Regional Institute of Occupational Health.

Methods tested in the assessments

Stage 1: Observation and simple measurements

At stage 1 a risk assessment of thermal environments by observation was conducted (13). Metabolic heat production was assessed according to ISO 8996 (7), where the assessment according to occupation and type of activity was used. This provides the roughest information of meta-

bolic heat production compared with analysing work type, posture and speed, or by measuring heat production. Measurements of ambient temperature and wind speed were conducted to assess the risk of frostbite injuries in the bare skin according to the windchill index (ISO TR 11079) (Table I).

Stage 2: Measurements

Table I shows the methods/parts of methods from ISO thermal standards related to cold stress/risk assessment which were tested at stage 2.

Training

Stage 1: Observation and simple measurements

A 30-min demonstration was given to describe the purpose and principles of ISO CD 15265 (13), ISO 8996 (7) and ISO 7726 (6). Following this, written instructions of the methods and assessment were provided, as well as the brochures to be filled in when conducting the observation. When specifically asked to do so, the instructor guided the observer in the workplace when conducting the first assessment.

Table I. Summary of the evaluated ISO thermal standards.

Standards (ref)	
ISO 8996 (7)	Assessment of metabolic heat production Stage 1: estimation from tables according to occupation and type of work Stage 2: estimation from tables according to group assessment procedure (speed + work posture+ work type)
ISO CD 15265 (13)	Risk assessment strategy for the prevention of stress or discomfort Stage 1: observation
ISO 7726 (6)	Instruments for measuring physical quantities Stage 1: air temperature, wind speed Stage 2: air temperature, wind speed, black globe temperature
ISO TR 11079 (10)	Analytical determination and interpretation of cold stress using calculation of the required clothing insulation (IREQ) and local cooling effects Stage 1: estimation of windchill Stage 2: calculation of insulation required (IREQ) and duration limited exposure (DLE)
ISO 9886 (8)	Evaluation of physical strain Stage 2: measuring local and mean skin temperature
ISO 10551 (11)	Assessment of the influence of thermal environment using subjective judgement scales Stage 2: assessment of thermal sensations, preference, tolerance, acceptance
ISO 9920 (9)	Estimation of thermal insulation of clothing Stage 2: estimation of clothing insulation values from tables

Stage 2: Measurements

The measurers were given a 45-min oral demonstration of the purpose and principles of the different methods to be used in the measurements (Table 1). Following this a 2-hour demonstration of measuring mean skin temperature (T_{sk}) was given. The instructions included information on the use of a datalogger, attaching skin temperature probes, downloading data from the logger to the computer and finally how to calculate T_{sk} . Furthermore, instructions were given on how to calculate insulation of clothing ensembles, determine metabolic heat production, as well as to calculate IREQ and DLE values.

After conducting the assessments a specialist in thermo-physiology confirmed that the measurements of T_{sk} were conducted accurately. In addition to an oral demonstration, written instructions for using the methods and conducting the assessment were provided. Furthermore, a measurement protocol was designed for conducting the assessments and analysing the results. This included a step-by-step description of the different phases of the measurement and analysing.

Instrumentation

Stage 1: Observation and simple measurements

Ambient temperature and wind velocity was measured by Silva Windwatch, Sweden.

Stage 2: Measurements

For measuring ambient temperature a temperature probe (YSI 405) attached to a datalogger (Grant 1200 Series) was used. In order to assess radiation temperature a standard black globe (diameter 15 cm) was used. Wind was measured with a windmeter (Silva Windwatch, Sweden). Small surface probes (YSI 427, YSI Inc., USA) were used for measuring skin temperatures. The temperatures were recorded with a 16-channel datalogger (Grant 1200 Series Squirrel meter/logger, Grant Instruments, England). For downloading the data a special computer program was used (Grant Instruments, Squirrelwise V 8.00).

Evaluation procedure

Stage 1: Observation and simple measurements

In order to receive experience from different types of work

situations each observer assessed five different workers. These were mainly chosen to represent various types of work regarding the types of cold exposure and work intensity. Furthermore, the observations were repeated three times for the five workers in order to evaluate the learning effect of using the methods.

Stage 2: Measurements

Each measurer began the assessment by attaching skin temperature probes to the worker. For determining T_{sk} an 8-point measuring system was used (8). In addition, thermal probes were attached to the left middle finger and left toe. The measurement interval was set to 1 min.

When the worker was dressing, each garment was recorded in a table indicating insulation values (9). If the garment could not be found from the tables it was not used when calculating the insulation value of clothing ensembles. The datalogger was switched on and a starting time was recorded. Following approximately 15 min of work outdoors, each measurer recorded the ambient conditions (temperature, black globe temperature, wind speed). The relative humidity was estimated to be 50 % for ambient temperatures below -5°C (10). Furthermore, metabolic heat production and subjective sensations of the worker were assessed at the same time. The subjective assessment included questions of thermal comfort, preference and acceptance asked separately for the whole body, fingers and toes. The assessment of ambient conditions, metabolic heat production and subjective sensations was repeated three times at 30-min intervals. The duration of each measurement was approximately 1.5 hrs (one work cycle).

Assessment of usability of the method

The usability of the thermal standards were evaluated by an inquiry method. A questionnaire was filled in connection with each assessment and separately for each method. The questionnaire included both factual as well as opinion-type questions. The questions were structured both as closed (pre set) and open ended. The following questions were asked: 1) the duration of the assessment (preparation, realisation, analysing of results) 2) opinion of the adequacy of the provided training (adequate to be able to perform the assessment, based on the received training some parts were un-

clear, considerable difficulties in performing the assessment) 3) how easy was the method to adopt (could be adopted immediately, required a few repetitions, required long term practising) and 4) free remarks of the limitations of the method.

Statistical analysis

In the statistical analysis the Kruskal-Wallis test was used for testing between differences in the duration of the assessment between different observers/measurers, as well as the different observations/measurements of one observer/measurer. Significance was set at $p < 0.05$.

RESULTS

Stage I: Observation and simple measurements

The total duration of the observation was on average 30 ± 30 min (mean \pm SD) (Table II). There were significant differences between observers in the duration of time to perform the assessment ($p < 0.001$). However, repeating the use of the methods did not change the duration of an assessment.

Analysing of the results could be immediately accomplished according to 88 % of the observations and required some minor calculations/analysing according to the rest of the observers. In the majority of the cases the instructions provided were considered adequate (88%). Some parts related to using the methods were unclear according to 12 %. These were mainly related to selecting the type of activity from tables and calculating the metabolic heat production (7). None of the observers considered the instructions inadequate. Adopting the method could be immediately achieved according to 74 % and required a few repetitions according to 26 %.

Table II. Total duration of the observation stage (n=66). The observation included the use of ISO CD 15265 (13), ISO 8996 (8) and ISO TR 11079 (10).

Activity (min)	min	max	mean	SD
Preparation	2	30	6	9
Realisation	5	35	11	8
Analysing	2	60	12	20
Total	7	95	30	30

Observers remarks on the different thermal standards
ISO CD 15265

- difficult to estimate workers' opinion about their thermal comfort without asking them
- the degree of contact cooling is lacking from the method
- difficult to estimate temperature merely by observation
- the categorisation of the condition "humidity" is difficult to understand

ISO 8996

- highly varying work renders it difficult to estimate the average heat production
- not possible to choose appropriate occupation from the table (missing)

ISO TR 11079

- highly varying wind speed complicates the estimation of windchill

Stage 2: Measurements

The total duration of level 2 measurements was on average 282 ± 229 min (Table III). There were significant differences in the duration of the assessment between different measurers ($p=0.031$). However, the duration of time to perform the assessment was the same when repeating the measurements. Analysing of the results required calculations that lasted from less than one hour (42 %) to a half day (42 %). The reminder (16 %) considered that analysing of the results required only short calculations.

The majority (62 %) considered that, based on the instructions and training provided, some parts related to the use of the methods were still unclear (Table IV). The reminder (38 %) considered that the measurements could be carried out well with the provided training. All respondents considered that the optimal use of the methods required a few repetitions.

Table III. Total duration (preparation, realisation, results analysing) of level 2 measurements (n=16). The measurements included the use of ISO 8996, ISO 9886, ISO TR 11079, ISO 10551, ISO 9920.

Activity (min)	Min	max	mean	SD
Preparation	5	120	29	28
Realisation	20	335	122	76
Analysing	15	480	131	185
Total	40	690	282	229

Table IV. The adequacy of the instructions and training provided for the different methods according to the measurers.

	ISO 10551	ISO 9886	ISO 9920	ISO 8996	ISO CD 15265	ISO 11079	Total
	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)
1	36 (4)	50 (4)	0 (0)	0 (0)	0 (0)	100 (1)	28 (9)
2	64 (7)	50 (4)	100 (5)	100 (4)	100 (3)	0 (0)	72 (23)
3	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Total	100 (11)	100 (8)	100 (5)	100 (4)	100 (3)	100 (1)	100 (32)

1=based on the training received the use of the method was successful

2=based on the training received the use of the method was moderately successful

3=based on the training received the use of the method was difficult

Remarks by the measurers of the usability of different thermal standards:

ISO 7726

- occasionally highly varying wind speed renders the estimation of average values difficult

ISO 8996

- highly varying activity level renders the estimation difficult, requires long time period
- adding the different components easily results in heat production values that are question ably high

ISO TR 11079

- calculation of IREQ and DLE requires a special computer program
- analysing of results required additional instructing

ISO 9886

- downloading of the data from the datalogger some what difficult to learn with the instructions provided

ISO 10551

- the questions related to preference, tolerance and acceptance are not always understood by the workers

ISO 9920

- individual small pieces of garments are lacking from the tables = underestimation of clothing insulation of ensembles

DISCUSSION

The purpose of the first stage of a risk assessment is to identify the majority of cold related hazards in places of work (2, 15). This stage provides qualitative information. In the present study the usability of the methods tested at stage I were considered to be relatively practical by the observers. The average duration of performing an obser-

vation was relatively short (~30 min). The relatively large deviation in the duration of an assessment was probably due to the fact that the observers were instructed to use the time needed to get an overview of the work situation. Therefore, persons more familiar with the work content used less time for the assessment. The training in this study was considered adequate to ensure that the methods could be adopted immediately. The amount of training corresponds to the recommendations for the observation stage of ISO CD 15265 (15). The main difference was that in the present study the instructions were given orally by the instructor.

A few remarks related to the contents of the standards were given by the observers. Some of the classification within the categories of ISO CD 15265 did not fit in with cold-related assessment, or the classification was not clearly understandable. Furthermore, the estimation of heat production from tables by occupation (7) does not cover all occupations.

The purpose of second stage cold risk assessment is to provide more detailed and quantitative information of the cold related hazards. This stage should be performed by specialists with adequate competence with a more thorough understanding in e.g. ergonomics. It is however recommended that this stage should not require too complex or expensive instrumentation and measurements (15). With the methods tested, protocol and training the duration of the risk assessment took on average approximately 4h 40 min (preparation, measurement, analysing). The large deviation in the duration was due to differences in analysing the results, which varied from one hour to a half a day.

The training provided in the present study was not entirely sufficient according to the majority of the persons conducting the measurements. Additional instructions were frequently asked for, especially when analysing the results. Although the collecting of the data was successful, the measurers considered that the use of the methods required a few repetitions in order to be performed in an optimal way. However, this could not be observed in the duration of the assessments, which was the same between the different repetitions. It is worth noting that all of the measurers had either a background in occupational health care or were otherwise orientated to occupational health and safety.

The measurers provided remarks about the usability of the methods at stage 2. For highly varying ambient or

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working conditions it was considered difficult to receive a reliable estimate of e.g. wind speed (6) or metabolic heat production (7). The assessment of a true average value would require repeated assessments for extended periods. Some of the methods used lacked relevant information to allow complete evaluation of the results (9). The workers did not always understand correctly the questions related to the subjective assessment (especially acceptance and preference) (11), although they were instructed to answer the questions according to instructions of the standard. Furthermore, the method should be applied repeatedly in order to receive a reliable overall mean over a certain period of time. This would require, especially in varying conditions (climatic, workload), a considerable amount of data. Concerning the measurement of mean skin temperature (8) it was considered laborious to perform and required a significant amount of time for preparation, as well as analysing. Moreover, although the training provided for calculation of the IREQ index (10) was considered sufficient, calculating and analysing the results need practising. As separate remarks the occupational nurses further indicated that using the methods needs special instrumentation which is not available in occupational health care units.

The study identified usable and practical elements from ISO thermal standards that could be used in more advanced cold risk assessment. These could include subjective assessment of thermal conditions (11), estimation of heat production and clothing insulation from tables (7, 9), measuring temperature and wind speed (6) and calculating the wind-chill index (10). The evaluation of the results by using these methods would require separate criteria values (e.g. tables or charts) (5). It is further recommended that mean skin temperature (8) and IREQ index (10) is determined in association with specific cold related problems requiring expertise. Occupational health care institutes, occupational hygienists or other expert institutes with adequate competence should use these methods requiring special instrumentation or involving more complex analysing.

In conclusion, the study provided information about the usability of ISO thermal standards from end users in the workplace and occupational health care. The methods tested at stage I were considered usable in workplace assessments. In addition, the training provided was considered to be sufficient for performing the assessment. The methods

used at stage 2 were more laborious to perform. In addition, the provided training at this stage was not entirely sufficient, which was mostly related to difficulties in analysing the results.

A c k n o w l e d g e m e n t s

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