Evaluation on legislations and standards for working in severe cold thermal environment

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ABSTRACT
Severe cold exposure is present in indoor and outdoor working activities, affecting the core and skin temperatures, working performance, health and safety of humans. The aim of this work was to evaluate the justification of work-rest periods and physiological limits set by present legislations and standards for working in severe cold thermal environment (SCE). The core and skin temperatures have been measured on one volunteer for 60 minutes at -20˚C. Results show a decrease in the temperatures during the first minutes of SCE with low physical exertion, but afterward as the physical exertion increased, the Tcore rapidly and Tskin slowly increased till the end of exposure to SCE. It was concluded that during exposure to SCE, Tcore and Tskin were managed with higher physical exertion and cold protective equipment.

KEYWORDS: cold exposure; core temperature; skin temperature; work-rest periods; physiological limits

1. INTRODUCTION

Exposure to severe cold thermal environment (SCE) is a significant risk factor present indoor in all seasons (e.g. frozen food industry) and outdoor during the winter season (marine, army, agriculture, forestry, mining, factories, construction, winter sport athletic disciplines and related occupations) (Mäkinen et al. 2006). SCE reduces core (Tcore) and skin body temperature (Tskin), lower muscle and physical working performance while increase muscle fatigue (Zlatar, Baptista, and Costa 2015). The exposure to cold influence musculoskeletal (Tochihara et al. 1995) and cardiovascular complains, which can further on lead to injuries and diseases (Mäkinen & Hassi 2009).

ISO (International Organization for Standardization) (ISO 15743 2008) give recommendations on risk and health assessment in cold environment (outdoor and indoor), and organizational preventive measures against cold risks. But it gives only general recommendations. Occupational safety and health professionals have to be trained to identify, estimate and manage the cold-related risk and health assessment.

The ISO 9886:2004 (ISO 9886 2004) give recommendations on physiological limits for Tcore of min 36.0°C. In exceptional circumstances, the ISO standard allows lower temperatures to be tolerated for short periods if subjects have been medically screened, if the local skin temperatures are simultaneously monitored and the relevant limits are respected; if the minimum local skin temperature is 15°C (in particular for the extremities); and if the worker is authorised to leave the work when he pleases.

Some of encountered national institutions give guidelines to conduct work assessments, create safe work plans, and monitor conditions to protect the workers (Canadian Centre for Occupational Health & Safety (CCOHS) 2016; Occupational Safety and Health Service of New Zealand 1997; Croatian Institute for Health Protection and Safety at Work 2016; Work Safe Victoria 2008; Safe Work Australia 2011; WorkCover NSW 2001).

The most detailed encountered recommendations are the Brazilian regulation NR29 (Fundação Jorge Duprat Figueiredo de Segurança e Medicina do Trabalho 2003), covering temperatures from +15 until -73˚C; the UK Food and Agriculture Organization (FAO) giving recommendations for values below -20°C (Johnston, W.A.; Nicholson, F.J.; Roger, A.; Stroud 1994); the German Institute for Standardization (DIN) from -5 until -30°C (DIN 33403-5 1997); while in Canada and New Zealand (Occupational Safety and Health Service of New Zealand 1997; Canadian Centre for Occupational Health & Safety (CCOHS) 2016), the recommendations cover temperatures below -26°C, based on the document published by the American Conference of Governmental Industrial Hygienists (ACGIH).

The aim of this work was through measuring Tcore and Tskin, evaluate the justification of work-rest periods and physiological limits set by present legislations and standards for working in SCE.

2. MATERIALS AND METHODS

The experiment was conducted at the Laboratory for the Prevention of Occupational and Environmental Risks (PROA), University of Porto. The experiment was approved by the Ethics Committee. A medical examination of the volunteer was conducted in Hospital São João, Porto, Portugal, A written consent was read and signed before the experiment started. The air temperature outside the climatic chamber was 18°C, and inside -20°C (SCE).

The experiment was conducted in the climatic chamber fitoclima 25000EC20. Tskin was measured with bioplux skin temperature sensors. The sensors were put according to ISO 9886:2004 (ISO 9886 2004) on 8 measuring points: forehead (Sk8), right arm in upper location (Sk7), right scapula (Sk6), left upper chest (Sk5), left arm in lower location (Sk4), left hand (Sk3), right anterior thigh (Sk2) and left calf (Sk1). Tcore was measured through intra-abdominal temperature with an Equivital Ingestible Pill Sensor.

The volunteer wore special cold protective equipment (jacket with a hood, trousers, boots and gloves) above their normal cotton clothing (socks, underpants, undershirt, trousers, thinly long-sleeved shirt, and sweater). The trial duration was 3 hours with 60 min of exposure to SCE. The mean Tskin was calculated using the weighting coefficients as suggested by ISO 9886:2004.

3. RESULTS

Different work/rest recommendations for properly dressed healthy workers using cold protective equipment at -20°C are illustrated in the following table 1:

Figure 1 shows the results of Tcore and Tskin variations through the trial. On the left side axis are illustrated Tskin values, while on the right side are the Tcore values. The vertical lines represent the phase start/end and the period of exposure to cold (SCE).

Table 1. Work-rest recommendations

Given by	Category	D ex (min)	Int ex (min)	RecT (min)
BR NR29	-18.0 to -33.9	240	60	60
FAO	-20>		50	10
DIN	-18 to -30		90	30

* D ex=total daily exposure; Int ex=Maximal interrupted exposure; RecT=Recovery time

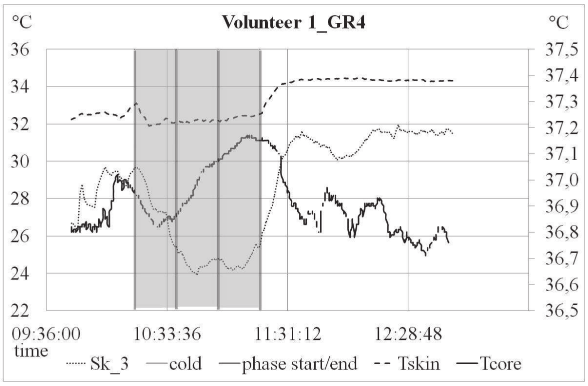

Figure 4. Results of the left hand (Sk_3), Tskin and Tcore temperature variations

4. DISCUSSION AND CONCLUSIONS

As illustrated in the figure 1, all measured temperatures increased in the first 30 minutes. The reason was that the sensors were put without clothes, afterward they dressed normal clothes which resulted in increasing of their temperatures. Ten minutes before exposure to SCE, the volunteers put the cold protective clothes which resulted in a second increasing.

The left hand (Sk_3) had the biggest decrease of all measured Tskin points. Afterward, it started slowly to increase which could be associated with more manual work. After SCE, hand skin temperature recovery period was less than 10 minutes to increase to the previous value (without gloves). Afterward, the hand temperature continued increasing.

The mean Tskin decreased from 33°C to 31.9°C in the first 7 minutes of exposure, where was a low physical exertion (PhyE) activity, but as further-on, the PhyE increased, the Tskin remained stable and slowly increased till the end of exposure to SCE. Tskin recovery period at comfortable room temperature took 2 minutes to increase to the value before SCE. Afterward, the mean Tskin continued increasing to 34.4°C.

The Tcore decreased in the first 10 minutes of exposure to SCE, where was a low PhyE activity, but as further on the PhyE increased, the Tcore increased and continued increasing till the end of exposure.

While some countries give precise regulations and recommendations on work/rest periods in cold workplaces, the ISO gives recommendations only on lowest core and skin temperatures, risk and health assessment in cold environment (outdoor and indoor), and organizational preventive measures against cold risks. Both approaches appear to have advantages and disadvantages. The regulations and recommendations by countries with work/rest periods give an approach which is easy to implement, but do not consider type of PhyE of the worker, therefore in some cases might result with too short or too long recovery period. The ISO 9886:2004 recommendations with lowest/highest core/ skin temperatures give an approach which is difficult for organizations to implement, requiring complex equipment, procedures and knowledge to analyse and interpret results.

Tcore and Tskin obtained results show that with higher PhyE, physiological ISO 9886:2004 limits are not reached. With proper PhyE and cold protective equipment, after the initial decrease, all measured points stabilized and didn't continue to decrease. On contrary from what was suggested, with higher PhyE, Tcore was increased in SCE. The results from measured skin points show that the recovery to values prior to SCE occur in 10 min after 60 of SCE.

In conclusion, with this short study it is shown that there might be space to improve both the legislations and standards. With higher PhyE, physiological limits set by ISO were not reached. With medium PhyE, Tcore increased and Tskin remained stable even during exposure. The recovery period for all measured points was less than 10 min. Further studies should be conducted with bigger sample in order to be able with consistency to evaluate and question the justification for work-rest periods and recovery time of recommendations set by BR NR29 and FAO. For evaluating DIN 33403-5, there is a need for longer SCE exposure. There is a need also for further studies regarding organizational, physiological parameters or/and health challenges which might be a reason for setting current recommendations for maximal interrupted exposure and recovery time.

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