

Use of drinking masks during extended mine rescue operations

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Mine rescue deployment – *current questions*

- Demographic change does not stop at mine rescue brigades ... how do we deal with the growing average age of German rescue brigades and the associated decline in physical performance and climate tolerance?
- Can the exhaustion caused mainly by loss of fluids, especially in a climatically stressful deployment, be delayed by the use of drinking masks?
- Can this extend the possible duration of a deployment or, alternatively, make a deployment easier (especially for older members of the brigade)?



Emergency operation and standard exercise – *physiological basics*

- Standard duration of operation: two hours for medium-hard work
- Respiratory rate (RR) of around 35 to 40 l/min, corresponding to an oxygen consumption of around 1.4 to 1.6 l/min
- Even below an ambient temperature of around 30 °C, an average core body temperature of 38.5 °C can be reached in the team after two hours ... this is the occupational health criterion for the mine rescue team to stop working under breathing protection
- Longer missions and “4-hour exercises” are therefore only possible with a lower workload: respiratory rate up to around 25 l/min, this is e.g. fast walking



Climate table for hot and wet climate and light work wear (GER)

Climate table for light work wear without and with (grey numbers) cooling vest – deployment time in min

Difference between dry bulb and wet bulb temperature (°C) - measurement with Assmann psychrometer

	0	1	2	3	4	5	6	7	8	9	10	
30	95 *											30
31	65 *	90 *										31
32	55 60	60 *	85 *									32
33	50 60	55 60	60 *	80 *	115 *							33
34	45 60	45 60	50 60	60 *	75 *	105 *						34
35	40 55	40 60	45 60	50 60	55 60	70 *	100 *					35
36	35 45	40 55	40 60	45 60	50 60	55 60	65 *	95 *				36
37	30 40	35 45	35 50	40 60	45 60	50 60	55 60	60 *	90 *			37
38	30 35	30 40	35 45	35 50	40 55	45 60	50 60	55 60	60 *	80 *		38
39	25 30	25 35	30 40	35 45	35 50	40 55	45 60	50 60	55 60	60 *	75 *	39
40	25 30	25 30	25 35	30 40	30 45	35 50	40 55	45 60	45 60	50 60	60 *	40
41	20 25	20 25	25 30	25 35	30 40	30 45	35 50	40 55	40 60	45 60	50 60	41
42	20 20	20 25	20 25	25 30	25 35	30 35	30 40	35 45	40 55	40 60	45 60	42
43	15 20	20 20	20 25	20 25	25 30	25 35	30 35	30 40	35 45	35 50	40 60	43
44	15 15	15 20	20 20	20 25	20 25	25 30	25 30	30 35	30 40	35 45	35 50	44
45	15 15	15 15	15 20	20 20	20 25	20 25	25 30	25 30	25 35	30 40	35 45	45
46	15 15	15 15	15 15	15 20	15 20	20 20	20 25	20 30	25 30	25 35	30 40	46
47	10 10	10 15	15 15	15 15	15 20	15 20	20 20	20 25	20 25	25 30	25 35	47
48			10 15	15 15	15 15	15 15	15 20	20 20	20 25	20 25	25 30	48
49				15 15	15 15	15 15	15 15	15 20	20 20	20 25	20 25	49
50					10 10	15 15	15 15	15 15	15 20	20 20	20 25	50
51						10 10	15 15	15 15	15 15	15 20	20 20	51
52							10 10	15 15	15 15	15 15	15 20	52
53									10 15	15 15	15 15	53
54										10 15	15 15	54
55											10 15	55

Working time max. 120 min
* without cooling vest

Working only in coordination
with rescue command center

And if it gets warmer? – *climatic stress under breathing protection*

- Determination of the maximum permissible working time according to the temperature and humidity measured during operation, using climate tables
- In general, only light work with an RR of 25 l/min or an oxygen consumption of around 1.0 l/min is permitted here ... and strictly speaking, this only applies to younger, well-trained mine rescuers!
- The climate tables were developed in series studies with average 35-year-olds and later verified up to a maximum of 45 years of age
- Therefore, the duration of use according to the tables should be shortened if necessary for mine rescue personnel older than around 45 years and/or “less fit”, or not acclimatized in a warm environment



Time management in exercise and deployment – *like a professional boxing match*

- “Self-pacing”, the alternation between work and rest, especially in a hot environment, must be learned individually during exercise
- In the case of a medium climatic operation with a typical duration of 40 to 50 minutes (“professional boxing match”), three-minute “work rounds” should alternate with one-minute breaks
- In the case of longer operations lasting up to 120 minutes (or the standard exercise), this rhythm should be extended proportionally to 3-minute breaks after every 10 minutes of work
- Adhere strictly to the climate tables – no “final sprint” is possible!



Fluid intake under breathing protection

- Fluid intake while using breathing protection is not yet provided for in climate tables, but would be possible with a drinking mask
- “De-hydration” is a major cause of the rapid decline in physical and mental performance and rapid exhaustion under climatic conditions, especially in the medium and light temperature range – i.e. for around 40 to 120 min deployment time according to the climate tables
- The prospect of extending deployment times or alternatively making work easier by drinking during deployment is becoming increasingly important in view of the growing average age of mine rescue teams in Germany



Key data of the research project

- The increase in core body temperature during a standard mine rescue exercise is well known from earlier series studies at the Essen/ Herne mine rescue centers
- By means of instrumented comparative exercises of a team of test subjects, exercises with re-hydration (drinking mask) can be compared with concurrent exercises without re-hydration as well as with corresponding data from the past
- During all exercises, the core body temperature at the beginning and end of the exercise and, if necessary, other physiological data are collected in accordance with occupational health guidelines

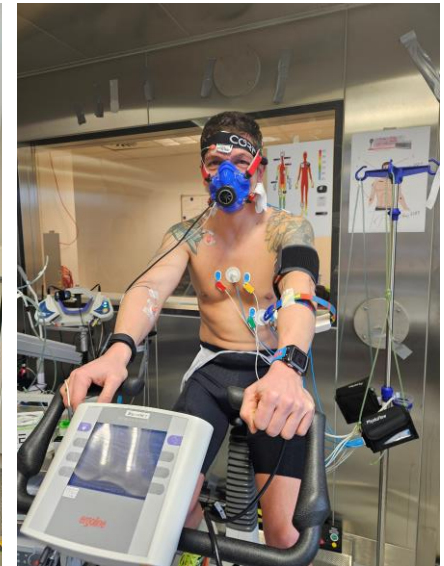


Test series starting in fall 2023

- Six comparison exercises (three with and three without re-hydration) with a group of 5 to 6 subjects (start fall 2023)
- 120-minute standard exercises according to German Mine Rescue Committee (DA GRW) guidelines: dry temperature 29 to 30 °C, relative humidity 50 to 60 %
- Precise timing of the movement and work profile of the exercisers analogous to earlier basic studies in the Essen/ Herne Mine Rescue Centers (1994 to 2006)
- Continuous recording of core body temperature and heart rate using a core system
- In addition, rectal body temperature measurement 10 minutes before the start and after the end of the exercise, and determination of the fluid balance during the exercise by weighing, as well as blood sampling for lactate measurement during the exercise breaks
- Approx. 500 to 600 ml fluid intake before the start of every exercise, and three breaks to drink as required during each of the three exercises with fluid replacement

Findings from preceding performance diagnostics in the IPA

Parameter	Results (average value/ standard deviation)
Age (years)	42,30 ± 5,90
Height (cm)	180,01 ± 0,15
Body mass (kg)	85,30 ± 2,90
BMI (kg/m ²)	26,20 ± 1,30
Power output (Watt)	285,70 ± 20,21
Performance (%)	+ 25,30 ± 10,70



Result: The test collective is healthy, of normal weight and very well trained.

Cycle ergometer/ 1st strength exercise at pulling machine (60 pulls)



Start of standard
exercise



Cycle ergometer
(15 min)



Pulling machine

Standard exercise round 1 (a)



Fluid intake



Blood gas
analysis



Maze

Standard exercise round 1 (b)



Breathing
protection gallery
section 1



Fluid intake



Breathing
protection gallery
section 2

Standard exercise round 1 (c)



Pulling machine
(60 pulls)



Fluid intake



Blood gas
analysis

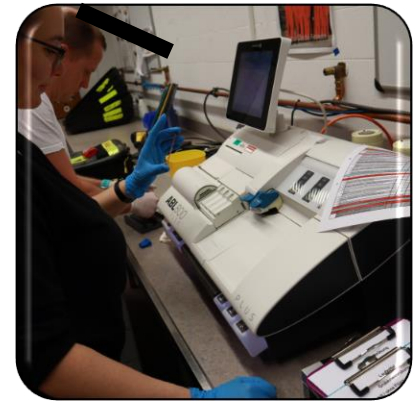
Standard exercise round 2



Breathing protection
gallery (round 2)

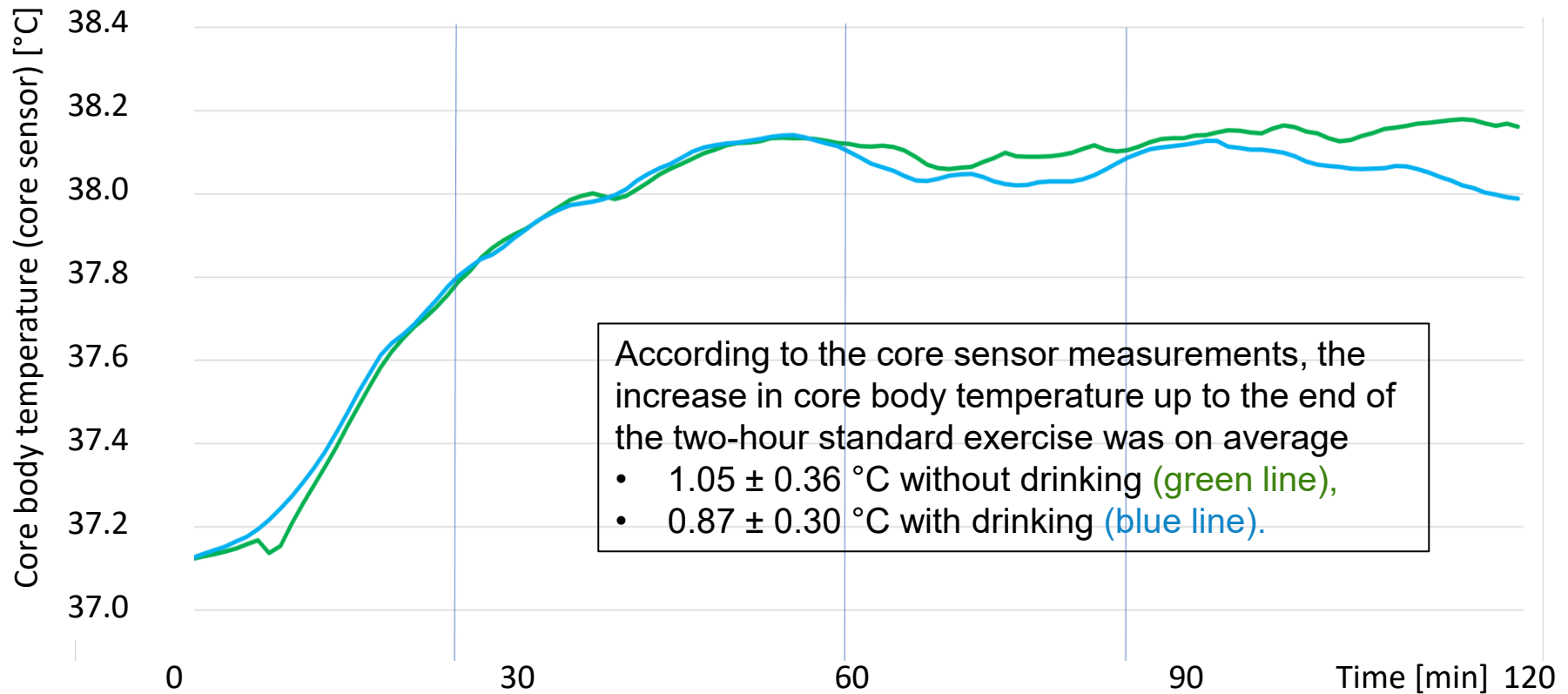


Pulling machine
(60 pulls)



Blood gas analysis
=> end of exercise

Findings from the exercises – *main result*



Evaluation

- The rise in core body temperature during a standard exercise can be slowed down by taking in fluids while wearing breathing protection
- This reduces the proportion of physical exhaustion caused by the rise in temperature
- Reaching the maximum recommended core body temperature of around 38.5 °C can be delayed
- The above-mentioned delay is around 20 minutes for a 120-minute standard exercise (RR = 35 to 40 l/min)

Further occupational health issues and results

- The collective studied is healthy, of normal weight and very well trained
- The temperature level of the core measurements is approx. 0.3 °C below that of the rectal measurements from current and previous data (difference due to measurement methodology) – for this reason, the results of the core measurements are only used here regarding the difference without/ with drinking
- The occupational health termination criterion for the deployment of mine rescue teams under breathing protection (38.5 °C) was not exceeded on average, either with or without drinking, based on the higher temperature level of the individual rectal measurements
- There was only a very small influence of drinking on the course of the heart rate
- The oxygen content in the blood is not the limiting factor during exercise
- The load during the exercise is above the “endurance threshold”, i.e. there is an intermittent high load (see footnote 3, “boxing match”)
- There is only a small but positive effect on electrolyte concentrations

Recommendations for mine rescue practice

- In practice, the delayed rise in core body temperature caused by drinking should be used primarily to compensate for typical pre- and additional stresses of a two-hour mine rescue operation with moderately heavy work, e.g.
 - Carrying the loaded stretcher, or other heavy manual work with a temporary increase in the respiratory rate (RR) to more than 35 to 40 l/min
 - Approach to the fresh air base (FAB) under difficult climatic conditions
 - Higher average age of the mine rescuers deployed, i.e. older than around 45 years
- No conclusions can yet be drawn from the current state of the investigations as to the benefits of fluid intake during operations lasting less than 120 minutes, which are shortened according to the climate tables
- Further questions regarding climate, duration of deployment, type of workload or clothing should be investigated in additional test series

Literature

1. Funkemeyer, M./ Kampmann, B./ Piekarski, C.: Belastung und Beanspruchung der Grubenwehrmitglieder. Glückauf 130 (1994), 591/596.
2. Bresser, G./ Funkemeyer, M.: Bestimmung der Einsatzdauer der Grubenwehr. Glückauf-Forschungshefte 51 (1990) 157/163.
3. Wolperding, T.: Untersuchungen in einem Klimaraum zur Beurteilung der Beanspruchung hitzeexponierter Bergleute. Kali und Steinsalz 11 (1992), Nr. 1/2, 18/23.
4. Kampmann, B./ Bresser, G.: Streuung der Beanspruchung bei einer Standardübung der Grubenwehr: Längsschnitt für vier Übungsteilnehmer über 10 Jahre. Bericht zum 52. Kongress der Gesellschaft für Arbeitswissenschaft. GfA-Press, Dortmund, 2006.
5. Mine Rescue Heat Stress Report. Workplace Safety North, Station Main, North Bay, Ontario, CA, 2014, https://www.workplacesafetynorth.ca/sites/default/files/resources/Mine_Rescue_Heat_Stress_Report_2014.pdf. [accessed 16.03.2024]
6. Hermülheim, W.: Zur Anwendung von Grubenwehr-Klimatabellen. Tagung der Berufsgenossenschaft Rohstoffe und chemische Industrie (BG RCI) für Oberführerinnen und Oberführer von Grubenwehren, Essen, 07. – 08. November 2018.
7. Hermülheim, W.: Das Grubenrettungswesen in Deutschland nach dem Ende des Steinkohle-bergbaus. Mine Rescue Services in Germany after the End of Hard Coal Mining. Mining Report Glückauf 158 (2022), 14/30.
8. Bresser, G./ Kampmann, B./ Piekarski, C.: Stress and Strain of Mine Rescue Teams during a Standard Training Procedure. Appl. Occup. Environ. Hyg. 12 (12), Dec.1997, 951/956.
9. Leitlinien des Deutschen Ausschusses für das Grubenrettungswesen für Organisation, Ausstattung und Einsatz von Grubenwehren, Stand Juni 2022, <https://deutsche-grubenrettung.de/wp-content/uploads/2022/07/Leitlinien-Grubenrettungswesen-Stand-2022.pdf> [accessed 16.03.2025].
10. Steinbach, D./ Marek, E. M./ Hermülheim, W.: Auswirkung von Flüssigkeitszufuhr während eines Grubenwehreinsatzes auf die Körperkerntemperatur. Zweite gemeinsame Tagung der BG RCI für Leiterinnen und Leiter von Gruben- und Gasschutzwehren, Atemschutz-mannschaften und Feuerwehren aus Betrieben unter Bergaufsicht, Soltau, 17./18.04.2024.

**Vielen Dank
für Ihre Aufmerksamkeit.**

Thank you for your attention.



All illustrations: BG RCI – Herne Mine Rescue Center