DETERMINING TOLERANCE TIME IN ENCAPSULATED ROOMS - PHYSIOLOGICAL CONSIDERATIONS

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Heat stress and quality of air are the main environmental factors which are considered to determine tolerance time in encapsulated shelters. During the Gulf war the entire population of Israel were enforced by the Civil Defence Authorities to use CW protective masks and to stay in totally encapsulated rooms which were considered impermeable to chemical agents. During the Gulf war which took place in the winter season no limitations were anticipated to rise regarding heat stress. From theoretical considerations, however, based on metabolic rate, tolerance time in the encapsulated rooms was predicted to be approximately 60 min/m^3 (1). Nevertheless, data accumulated from studies during the 2nd WW indicate that people can endure several hours in an erea of 0.18-0.22 m^2/person (2). The discrepance between the literature and the theoretical considerations was the basis of the present study. It was conducted to define the tolerance time in an encapsulated room by considering both factors: heat stress and air quality.

MATERIALS and METHODS

Subiects: 35 young motivated soldiers gave their informed consent to participate in this study. 28 participants were female soldiers (age 19±1 yrs, weight 54.5±1.5kg A_D 1.63±0.02m^2) and 7 were male soldiers (age 19f1.2, weight 63.2±3.1kg, A, 1.64±0.02m^2). All participants were medically examined and were healthy for the last 2 weeks prior testing.

Environment: The study was carried out in the inner part of the coastal area of Israel during the summer season (Ta=30.6±0.4°C; rh=40.9±4.9%).

The encapsulated room's area was 8.4 m^2 and its volume 22.2 m^3.

Experimental setup: Seven subjects were tested each day. Exposure started at 11:00 AM after initial measurements were taken (HR, Tsk, weight). The participants were instructed to stay in the sealed room as long as they could endure while wearing a CW protective mask. They could watch TV programs, read, or play quite group games. Tolerance time was determined by the time the room had to be opend for one of the following reasons: a) one of the subjects wished to terminated his participation, b) O, or CO, concentrations reached safety limits (O_2<17%; CO_2>34), c) after 6hrs, which was set to be the maximal exposure time for this study. Taking off the mak during the exposure was permitted; tolerance time with

mask was recorded. Chemical toilets were located inside the room. During one day a fan was installed inside the room.

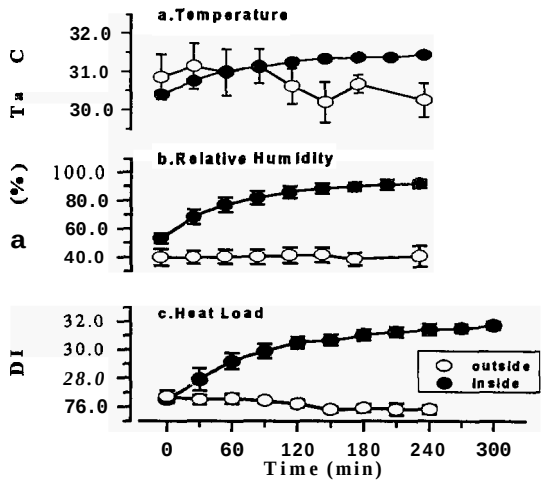
A medical technician was attending inside the sealed room and was counted as one of the test subjects. The technician was responsible for all measurements taken during the exposure. A physician was attending outside the room and was in close touch with the participants by a closed video circuit.

Measurements: Environmental parameters: ambient temperature and relative humidity were recorded every 30 min. by an electronic temperature/humidity recorder (Testoterm 452) inside the room and outside it. Heat stress was determined by the discomfort index according to Sohar et al. (3). Inspiratory air quality (CO_2, O_2 concentrations) was recorded every 30 min in close vicinity to the subject's month-nose area by an oxymeter (Datex). Heart rate was monitored every 30 min by a pulse oxymeter monitor (Datex). Chest skin temperature was recorded by a termistor (YSI-401) every 30 min. Fluid balance was calculated from differences in weight which were taken (±10g) immediately prior and after exposure. Fluid consumption was ad lib.

RESULTS

Environmental Conditions: The climatic conditions which prevailed during the 5 days of the study are depicted in fig 1 (mean±SEM); ambient temperature was 30.6±0.4°C and relative humidity was 40.9±4.9%; heat load was 26 DI units, which is considered as a moderate heat load (3). The environmental conditions which developed inside the sealed room are summarized in fig. 1.

Fig 1: Changes in environmental conditions outside and inside the sealed room



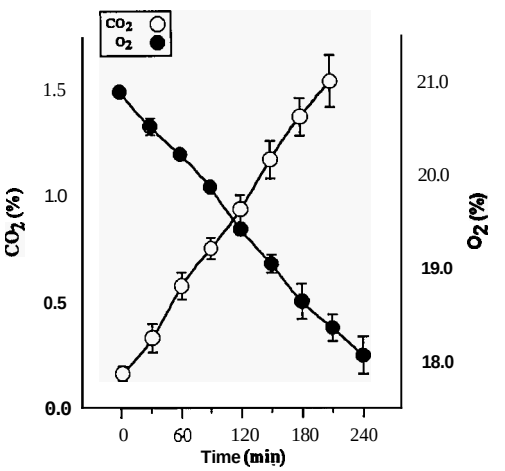
Temperature was slightly above the ambient temperature (+0.7°C); relative humidity reached within 30 min maximal levels of 90±2%. Heat load was accumulating and already after 30 min it was considered as heavy heat load (>28 units).

Air quality: Inspiratory oxygen concentration was steadily decreasing concomitantly with a rise in CO, (fig 2). Linear regression lines ($r=0.99$; $p<0.001$) could be adapted for the changes in O_2 and CO_2 concentrations as follows (t=time in minutes):

$$[O_2]=20.9-0.01 \cdot t \qquad [CO_2]=0.16+0.0065 \cdot t$$

Accordingly, safety limits calculated from these regression lines ($O_2<17\%$ $CO_2>3\%$) were reached within 5.5-7h.

Fig 2: Changes in O_2 and C02 concentration in the sealed room



Tolerance time: Mean tolerance time was 240±35 min. Only during the exposure in which the fan was operating tolerance time was 360min. The reason for terminating the exposure was subjective discomfort (3/5 days) and O_2 concentrations less than 17% (2/5 days).

The time during which the subject tolerated the protective mask was significantly shorter. The time elapsed until the 1st subject took off the mask was 20min; mean tolerance time with a mask was 170±40 min.

Physiological Variables: No significant changes were observed in HR during the exposures which was in the range of 82-86 bpm. This reflects a relatively low metabolic rate of the sbjects. In fact the calculated VO_2 was about 375±13ml/min. Skin temperature was in the range of 35.2-35.5°C. Noteworthy, on day 5 when a fan was operated skin temperature was in the range of 34.5-35.1°C.

Since the subject were able to drink ad lib; no dramatic levels of dehydration could be observed.

CONCLUSIONS

The subjects who participated in this study are not a typical population and therefore the results are not reflecting the responses of the entire population. Nevertheless, it can be concluded that:

1. The overall tolerance time was 3-6h, but the participants tolerated the masks for a much shorter period.
2. Tolerance time based on changes in air quality is probably higher than is expected according to the prediction model of Givoni which results from a low energy expenditure.
3. At least for the young healthy motivated population heavy heat load, though very discomfort, is not necessarily a limiting factor, as long as exposure is at rest and hydration level is adequate.
4. A fan positioned inside sealed room may be a helpful tool to increase tolerance time.

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