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Defence R&D Canada – Toronto
Technical Report
DRDC Toronto TR 2004-200
December 2004

Canada

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Abstract

Purpose: The purpose of this study was to examine the physiological and psychological effects of working in two different environments that protect against chemical threats. **Methods**: Fourteen (9 male and 5 female) regular Canadian Forces personnel were divided into two groups and performed various command post (CP) duties in a chemical threat scenario environment while wearing individual protective ensemble (IPE) or in a collective protective facility (COLPRO) for 24 hours. Each group performed CP duties in each environment and had a 24 hour rest between each trial. During their trials, core temperature was recorded and measured by a radio pill system; heart rate (HR) was recorded and measured using polar technology, body water loss was evaluated by body weight changes, thermal comfort, feeling of fatigue and perceived mental effort were evaluated using index scales. **Results**: core temperature was slightly elevated in the IPE compared to COLPRO by 0.2°C. Average 24hr HR was significantly elevated by 8 beats·min^{-1}. Dehydration was significantly increased in the IPE environment; whereas, in the COLPRO soldiers were able to maintain hydration status. Thermal comfort and fatigue ratings were significantly worse in the IPE (warmer and more fatiguing) compared to the COLPRO. Mental effort to do the various CP duties was similar in both environments. Four of 14 soldiers while in IPE had severe headaches and one of the four was sick and one withdrew from the trial. This translated into a 28% casualty rate. **Conclusions**: It was concluded that even though core temperature was stabilized at a slightly higher level in IPE, this environment was more stressful than in COLPRO and led to inefficiencies.

Résumé

Objet: L'étude visait à déterminer les effets physiologiques et psychologiques du travail accompli dans deux contextes distincts qui assurent une protection contre les menaces chimiques. **Méthodes**: Quatorze militaires des Forces canadiennes (Force régulière) (9 hommes et 5 femmes) ont été divisés en deux groupes et affectés à diverses fonctions rattachées à un poste de commandement (PC) dans le cadre d'une simulation de menace chimique. Les sujets ont soit porté un équipement de protection individuelle (EPI) soit évolué dans une installation de protection collective (COLPRO) pendant 24 heures. Chaque groupe a exécuté des fonctions d'un PC dans chaque contexte et bénéficié d'une période de repos de 24 heures entre chaque essai. Au cours des essais, la température centrale de chaque participant a été enregistrée et mesurée au moyen d'une capsule télémétrique; la fréquence cardiaque (FC) a été enregistrée et mesurée au moyen de la technologie polaire; la perte d'eau corporelle a été évaluée au moyen des changements de poids corporel; le confort thermique, la fatigue et l'effort mental perçu ont été mesurés à l'aide d'échelles. **Résultats**: La température centrale était légèrement plus élevée (de 0,2°C) dans le cas d'une protection individuelle (EPI) que dans le cas d'une protection collective (COLPRO). La FC moyenne sur 24 heures était nettement plus élevée (de 8 battements à la minute)1. La déshydratation était sensiblement plus importante dans un contexte de protection individuelle, alors que dans un contexte de protection collective, les militaires ont pu maintenir leur équilibre hydrique interne. Sur les plans du confort thermique et de la fatigue, les militaires bénéficiant d'un EPI étaient nettement moins avantagés (sensation de chaleur et de fatigue plus grande) que les autres. Quant à l'effort mental requis pour l'accomplissement des diverses fonctions associées à un PC, il était comparable dans les deux contextes. Quatre des quatorze militaires portant un EPI ont souffert de céphalées intenses; un des quatre est tombé malade et un autre a abandonné l'expérience. Autrement dit, l'essai s'est soldé par un taux de pertes de 28 %. **Conclusions**: Il ressort de l'expérience que même si la température centrale s'est stabilisée à un niveau légèrement plus élevé en cas de port d'un EPI, ce contexte a engendré plus de stress que le mécanisme de protection collective (COLPRO) et a entraîné des pertes d'efficacité.

Executive summary

As warfare evolves it is apparent that an increasingly asymmetrical nuclear, biological, chemical (NBC) threat exists. Under such a threat a Canadian Forces (CF) soldier must perform his duties or mission while encapsulated in a chemical protective suit; better known as nuclear, biological and chemical clothing (IPE MOPP 4). There are occasions, however, where the wearing of the suit is prohibitive i.e., medical, command control communication and information, and maintenance roles. For such roles there are facilities that have been developed to allow a soldier unrestricted performance that occurs in the chemical suits. Such a facility is called a collective protection facility (COLPRO). The Directorate of NBC Defence (DNBCD) has tasked DRDC Toronto to explore the impact of the use of such a facility on current CF operations. Thus a field study was set up to do a direct comparison of COLPRO versus IPE MOPP 4 environments on command post duties. By conducting this comparison, information was generated that enabled DNBCD to better understand what value, if any, COLPRO would have for the CF in the future.

This report examined the physiological and psychological effects of working in the two different environments that protect against chemical threats. Fourteen (9 male and 5 female) regular Canadian Forces personnel were divided into two groups and performed various command post (CP) duties in a chemical threat scenario environment while wearing IPE MOPP 4 or in a COLPRO for 24 hours. Each group performed CP duties in each environment and had a 24 hour rest between each trial. During their trials, core temperature, heart rate (HR), body water loss, thermal comfort, feeling of fatigue and perceived mental effort were measured and evaluated. The physiological results showed that core temperature was elevated in the IPE compared to COLPRO, HR was significantly higher, and dehydration greater. The psychological results showed that the soldiers reported higher levels of thermal stress to the point on nausea and higher levels of fatigue in the IPE MOPP 4. Four of 14 soldiers while in IPE MOPP 4 had severe headaches and one of the four was sick and one withdrew from the trial. This translated into a 28% casualty rate. It was concluded that even though core temperature was stabilized at a slightly higher level in IPE MOPP 4, this environment was more stressful and fatiguing which in turn led to greater inefficiencies than in COLPRO environment.

Ducharme, M.B., Bell, D.G., Drolet, E. J.G., Boyne, S.J. 2004. Physiological and Psychological Effects of Working in COLPRO Compared to IPE in Command Post Personnel. TR 2004-200. DRDC Toronto.

Sommaire

Si l'on observe l'évolution des pratiques de guerre, il semble que l'on soit de plus en plus confronté à une menace nucléaire, biologique et chimique (NBC) asymétrique. Dans pareil contexte, tout militaire des Forces canadiennes (FC) doit porter une combinaison de protection contre les produits chimiques, également appelée combinaison NBC (EPI POSM 4), pour accomplir ses fonctions ou remplir sa mission. Il y a des cas, cependant, où le port de la combinaison nuit aux opérations, comme les interventions médicales, la communication et l'information liées au commandement et au contrôle et l'entretien. Il existe, pour ce genre de rôles, des installations spécialement conçues de manière à permettre au militaire d'accomplir ses fonctions sans les restrictions imposées par les combinaisons de protection contre les produits chimiques. Il s'agit d'installations de protection collective (COLPRO). La Direction de la défense nucléaire, biologique et chimique (DDNBC) a chargé RDDC-Toronto d'étudier les répercussions de l'emploi de ce genre d'installations dans le cadre des opérations actuelles des FC. C'est ainsi qu'a été entreprise une étude sur le terrain visant à comparer directement les effets de l'environnement COLPRO et ceux du port de l'EPI POSM 4 sur les fonctions associées à un poste de commandement. L'information ainsi obtenue a permis à la DDNBC de mieux comprendre l'intérêt que pourrait présenter l'installation de protection collective (COLPRO) pour les FC à l'avenir.

Ce rapport a porté sur les effets physiologiques et psychologiques du travail accompli dans deux cadres différents qui assurent une protection contre les menaces chimiques. Quatorze militaires des Forces canadiennes (Force régulière) (9 hommes et 5 femmes) ont été divisés en deux groupes et affectés à diverses fonctions rattachées à un poste de commandement (PC) dans un contexte de simulation de menace chimique. Les sujets ont soit porté un équipement de protection individuelle (EPI) soit évolué dans une installation de protection collective (COLPRO) pendant 24 heures. Chaque groupe a exécuté des fonctions d'un PC dans chaque contexte et bénéficié d'une période de repos de 24 heures entre chaque essai. Au cours des essais, la température centrale, la fréquence cardiaque (FC), la perte d'eau corporelle, le confort thermique, la fatigue et l'effort mental perçu ont été mesurés et évalués. Selon les indices physiologiques, la température centrale était plus élevée, la FC était nettement plus élevée et la déshydratation plus importante chez les sujets bénéficiant d'une protection individuelle (EPI) que chez ceux qui profitaient d'une protection collective (COLPRO). Si l'on se fie aux indices psychologiques, les militaires qui portaient un EPI POSM 4 auraient ressenti plus de stress thermique (au point d'éprouver des nausées) et de fatigue. Quatre des quatorze militaires portant un EPI POSM 4 ont souffert de céphalées intenses; un des quatre est tombé malade et un autre a abandonné l'expérience. Autrement dit, l'essai s'est soldé par un taux de pertes de 28 %. Il ressort de l'expérience que même si la température centrale s'est stabilisée à un niveau légèrement plus élevé en cas de port d'un EPI, ce contexte a engendré plus de stress et de fatigue et, partant, des pertes d'efficacité plus grandes, que le mécanisme de protection collective (COLPRO).

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Table of contents

List of figures

Acknowledgements

The Authors would like to thank the soldiers of the 2nd General Support Battalion for volunteering for these trials. We also appreciate the technical assistance of Bob Limmer, Jan Pope, Dan Richards and the OCdts of DRDC Toronto.

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Introduction

As warfare evolves it is apparent that an increasingly asymmetrical nuclear, biological, chemical (NBC) threat exists. Under such a threat a Canadian Forces (CF) soldier must perform his duties or mission while encapsulated in a chemical protective suit; better known as nuclear, biological and chemical clothing – "NBC gear". This chemical suit consists of a semi-permeable overgarment, impermeable rubber boots and gloves, and a rubber mask with a respirator attached. In a warfare zone, where there is the possibility of a chemical threat, the chemical suit is normally worn over combat clothing and boots, which in turn is layered over a T-shirt, underwear and socks. This amount of clothing and chemical protection is classified as the highest level of the soldier's individual protective ensemble (IPE) and is known as mission oriented protective posture 4 (MOPP 4). When not in a war and not in a chemical threat scenario the soldier would be wearing his regular combat clothing and boots and this would be classified as a MOPP 0 level. Although this IPE MOPP 4 ensemble protects the individual from a chemical threat, it is known that it impairs performance due to the additional heat stress associated with wearing this clothing (6, 18, 26). Even in a cool environment, extended wearing of IPE at the MOPP 4 level has produced casualties i.e., the inability of soldiers to perform their duties (22).

Any procedure, equipment or facility that can be used by the soldier to reduce the performance decrement and casualties associated with wearing IPE at the MOPP 4 level would be advantageous. A review by McLellan and Frim (16) pointed out that procedures such as heat acclimatization and improved fitness had little effect on tolerance times in MOPP 4 in hot environments and suggested that micro climate conditioning techniques would be more beneficial for the soldier. This latter point has been demonstrated by a number of authors (4, 5, 7, 13). Another approach that could help the soldier in this environment is the use of a portable pressurized facility. This facility could be used for a group of soldiers in a field situation where command post type duties would be performed (9, 10, 14, 27). This facility is call a collective protection facility (COLPRO) and consists of an enclosure within which personnel can operate without the requirement to wear the IPE at the MOPP 4 level. COLPRO has two main functions: to provide protection beyond IPE endurance limitations; and to protect specific facilities or functions, that would be operationally ineffective in a NBC environment (medical, command control communication and information, and maintenance roles).

The Directorate of NBC Defence (DNBCD) has tasked DRDC Toronto to explore the impact of COLPRO use on current CF operations. Thus a field study was set up to do a direct comparison of COLPRO versus IPE MOPP 4 environments on command post duties. By conducting this comparison, information was generated that will enable DNBCD to better understand what value, if any, COLPRO will have for the CF in the future. These trials were conducted between 22-26 August 04, at Canadian Forces Base Petawawa. During the trials, the outside environmental temperature ranged between 12°C and 23 ° C.

Purpose

The aim of this study was to compare the physiological and psychological stress of the COLPRO and IPE MOPP 4 on command post activities during a field simulated chemical threat scenario.

Method

Subjects

Fourteen CF personnel (5 females and 9 males) aged 31 ± 8 (mean ± SD) yrs, weight 74.9 ± 11.2 kg and height 170 ± 1 cm from the 2nd General Support Battalion gave their written informed consent for their participation in the study. The experimental protocol was approved by the DRDC Human Research Ethics Committee. The 14 soldiers were divided into two groups of 7. Each group performed 24 hours in COLPRO and 24 hours in IPE MOPP 4 environment with a 24-hour rest period in between conditions. During the rest period they went back to their regular activities and were not required to be in the area of the experiment nor in MOPP 4. During their time in the two conditions they performed command post duties described below. The total time for the trials including the rest period was 96 hours.

Procedures

Command Post Operations: The performance assessment environment was the operation of a Service Support Command Post (CP) for a major Land Force Exercise. The tasks performed during this activity include monitoring and logging radio communications; producing and promulgating both written and verbal orders; updating a mapboard with current unit information; and physical liaison with units external to the CP. The timing of the majority of the tasks performed was determined by the external units who promulgated the orders to the CP. In addition, the experimental staff inserted activities to ensure that each condition was evaluated consistently; for example each of the test conditions were required to produce at least one written transport request.

COLPRO Environment: The specific COLPRO system being evaluated was the Trelleborg COLPRO system, which has an air filtration and air conditioning system. The Trelleborg tent is designed to be raised in less than ten minutes. The tents can be connected to each other on the end-sides. Furthermore, cross-connecting tents can be connected on all four sides. Thereby a large area of complete tent coverage can be created. The tent material is a poly vinyl chloride coated synthetic fabric that is both flame and infra red resistant. The ground area for a single tent is 38 m^2 (Length 2.25 m x Width 5.20 m). The volume inside is 58 m^3 and the height under the ribs is 2.6 m. The COLPRO tents were set up with an operations centre, an ablution area, a rest/sleeping area and a storage area. Before entering the shelter, subjects were required to pass through a decontamination line. When not in the COLPRO shelter, subjects were required to wear their full IPE at a MOPP 4 level described below. Once they have entered the COLPRO shelter they operated in normal combat clothing. Temperature

within the COLPRO was maintained between 21 – 22°C and the relative humidity between 40 - 60%.

IPE Environment: The in-service chemical suit is a one-piece coverall with an attached hood and a combination Velcro and a two-way zip fastener front closure. The coveralls have three pockets, two breast pockets designed for carriage of ammunition magazines and one large pocket on the right thigh for maps, etc. Internal suspenders provide for an adjustment fit at the crotch. The wrist and ankles are closed with Velcro and an elastic stirrup is placed under the arch of the combat boot to hold the trouser leg down. The chemical warfare (CW) over boot is worn over the stirrup. The material of the outer shell is a woven nylon/cotton-twist cloth, dyed olive green and treated with water and a chemical repellent. The inner material is polyurethane foam, bonded to nylon tricot. The foam is impregnated with activated charcoal to absorb any CW agent vapour that penetrates the outer material. The insulation value of the IPE once the soldier is fully clothed at the MOPP 4 level is 2.35 clo. The physical layout of the CP for the IPE condition consists of multiple sections of modular tents similar to the COLPRO tents but without air conditioning and no pressurization to keep the chemical threat out. The tents opened to the outside environment. Within the tent there was an assortment of radios and computers for communication with outside units similar to those within the COLPRO. There was a briefing area and a mapboard to track the location and status of the brigade units. There was also a sleeping, eating and ablution area. Subjects performed the same duties in the IPE MOPP 4 environment as in the COLPRO environment. They performed all of the NBC drills associated with sleeping, working, resting, defecation, urination and eating. Subjects were required to wear IPE at a MOPP 4 level during test conditions for 24 hours. The work-rest cycles and hydration schedules proscribed in Nuclear, Biological and Chemical Defence (NBCD) Operations (B-JG-005-311/FP-001) were to be followed during the IPE MOPP 4 portions of the exercise. The post was to be manned for 24 hours. Temperature within the tent from 2100 hours on the night of the 22 August until 2000 hours on the night of the 23 August ranged from a low of 12° C to a high of 23°C, with mean temperature being 18°C. Relative humidity ranged from 40 – 80 %,with a mean of 60%. Temperature within the tent from 2100 hours on the night of the 25 August until 2000 hours on the night of the 26 August ranged from a low of 20°C to a high of 26°C, with a mean being 23°C. Relative humidity ranged from 70 – 85%, with a mean of 80%.

Physiological measures: Prior to performing the CP duties the subjects reported to the physiological monitoring preparation area. The subjects were instructed to swallow a radio pill (Model HT150002 ingestible core temperature body sensor, HQ Inc, Palmetto, FL, USA). They then had their nude weight measured on an electronic scale with a resolution of 5 g (Super Count, Setra Systems INC., Acton, MA, USA). They strapped around their chest a heart rate transmitter belt (Model Polar T 31, Polar Electro Inc, Woodbury, NY, USA). The subjects then dress for the appropriate environmental condition. Core temperature (°C) and heart rate ($beats \cdot min^{-1}$) were captured every minute thereafter, on a recorder (Model HT 150016 recorder, HQ Inc. Palmetto, FL USA) that was belted around the outside of the subjects clothing. At various times during the 24 hour experimental trials, core temperature and heart rate were monitored directly by an investigator for safety purposes and to ensure that the recorders were operating properly.

Hydration status or body water loss was determined by evaluating the nude weight of the subjects before and after the trials. In addition all fluids and food were weighed on another

electronic scale with a resolution of 0.01 g (3000C, Precisa Pag Oerlikon AG, Zurich, Switzerland) before being ingested and any leftovers were also weighed to determine how much the individual ate and drank. Further all human wastes (fecal and urinal) were also collected and weighed. From this information, an approximation of hydration status was determined.

Psychological measures: During the trials various psychological measures of thermal comfort, fatigue, and mental effort were evaluated via scaled charts. The investigators asked the soldiers to rate these psychological variables every hour from 0500 hrs until 2000 hrs. The subjects rated their thermal comfort (perceived thermal comfort scale) on a 13 point scale ranging from 1 "so cold I am helpless" to 13 "so hot I am sick and nauseated" (Annex A). They rated their feeling of fatigue (Fatigue Index) using an 11 point scale ranging from 0 "not tired" to 10 "extremely tired" (Annex B); and rated their perceived mental effort (PME) on a 10 point scale ranging from 1 "low easy, simple" to 10 "high demanding complex" (Annex C).

Statistics

The heart rate and core temperature mean values for each subject were determined over the 24 hour period and used in a one-way repeated analysis design to determine the difference between conditions (MOPP4 VS COLPRO). A one-way analysis of variance (ANOVA) was also used to determine the difference in food and fluid intake and waste produced for the two conditions. For the fatigue index, PME and thermal comfort values a two-way repeated analysis design (condition MOPP4 vs COLPRO, by time) was used. To correct for the violation of the sphericity assumption with the repeated factors a Huynh-Feldt correction was applied to the F-ratio (12). When the ANOVA yielded a significant F-ratio then a post hoc comparison of means was done with a means comparison contrast technique. Statistical significance was accepted at the $p \leq 0.05$ level.

Results

Core Temperature

Because of technical limitations, core temperatures were captured on 12 of the 14 soldiers and over 21 hours of the 24 hour period. The 3 hours that were lost were between 2000hr – 2300 hrs of the first evening in each condition. Mean ± SD of core temperature over the 21 hours for the IPE (MOPP 4) and COLPRO conditions were 37.1 °C ± 0.3°C and 36.9°C ± 0.3°C respectively. These values are not different from each other. The core temperatures change over time was lower in the early morning and higher in the afternoon following the natural circadian rhythm for both IPE and COLPRO conditions as noted in Figure 1. The highest core temperature observed was 38.3°C and this was in the IPE environment. The highest core temperature attained in the COLPRO was 37.7°C.

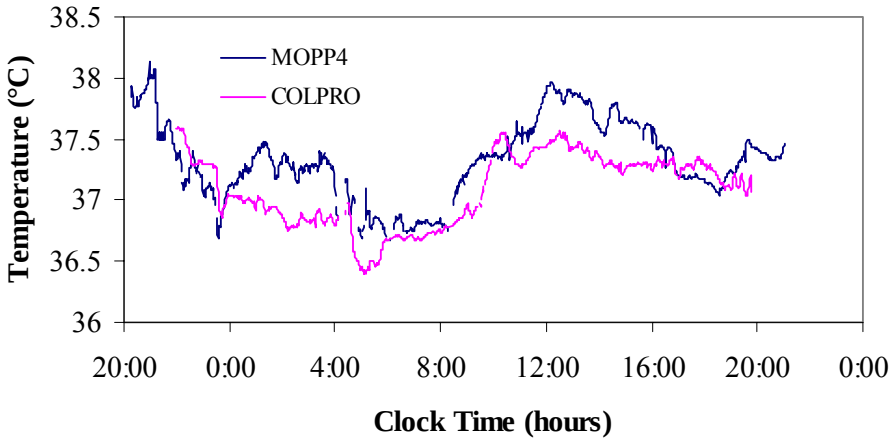

Figure 1. Core temperature of subject 6 while in the Individual Protective Ensemble (IPE – MOPP 4) condition compared to the Collective Protection tents (COLPRO) condition.

Heart Rate

Being in the IPE significantly increased HR compared to the COLPRO throughout the trials. Mean ± SD heart rate over the 24-hr period was 80 ± 6 and 72 ± 8 beats·min^{-1} for the IPE and COLPRO respectively. HR was generally higher during the afternoon compared to the early morning, and in general did not increase above 130 beats·min^{-1} as most of the activities were done while seated (Figure 2).

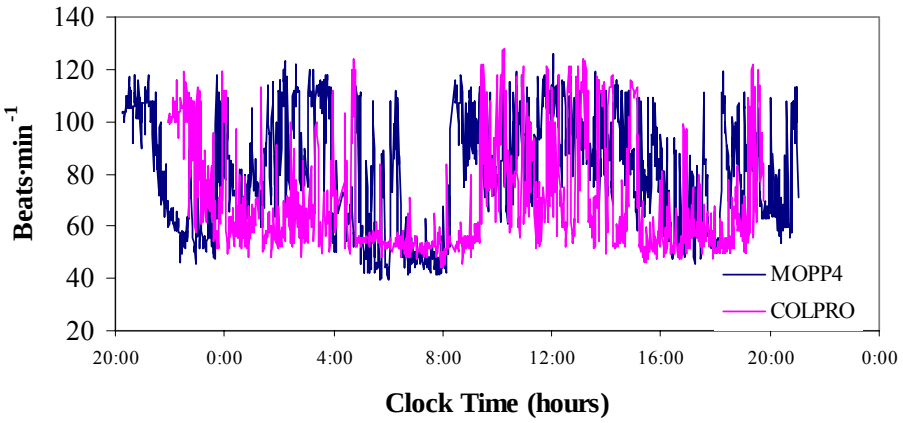

Figure 2. Heart rate of subject 6 while in the Individual Protective Ensemble (IPE – MOPP 4) condition compared to the Collective Protection tents (COLPRO).

Food, Fluid and Weight

Figure 3 shows that while in IPE the soldiers ate less and drank more compared to the COLPRO condition. They also lost more body weight: 0.5 kg in the IPE condition compared to 0.1 kg in the COLPRO environment. This weight loss was associated with water loss. The total water utilized during the 24-hr period (measured as fluid intake + weight change) was 2.68 litres for the IPE compared to 1.35 litres for the COLPRO environment.

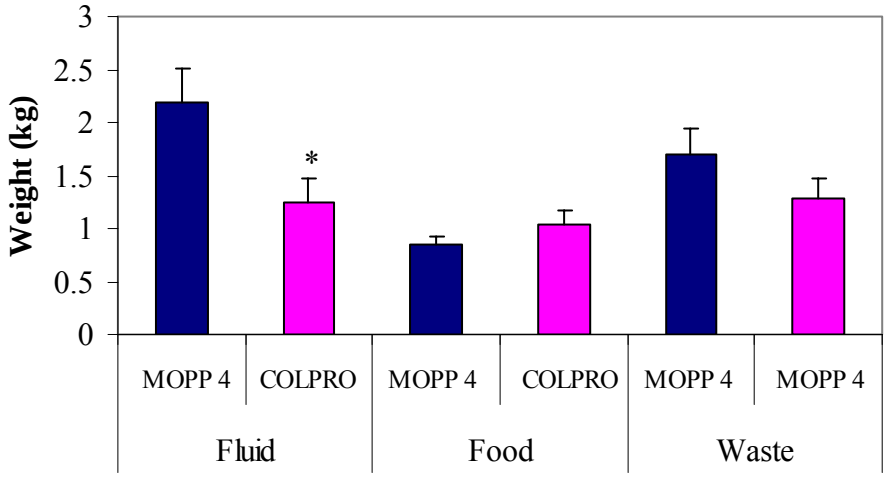

Figure 3. Mean ± see Food and Fluid intake (kilograms) and Weight lost of Soldiers in the Individual Protective Ensemble (IPE – MOPP 4) condition compared to the Collective Protection tents (COLPRO). * MOPP 4 significantly different from COLPRO.

Thermal Comfort

Although, core temperature was not significantly elevated in the IPE compared to the COLPRO trial, the IPE trial was rated as being significantly more stressful throughout (Figure 4). During the afternoon in the IPE condition, the thermal comfort ratings reached near maximal values in a number of subjects.

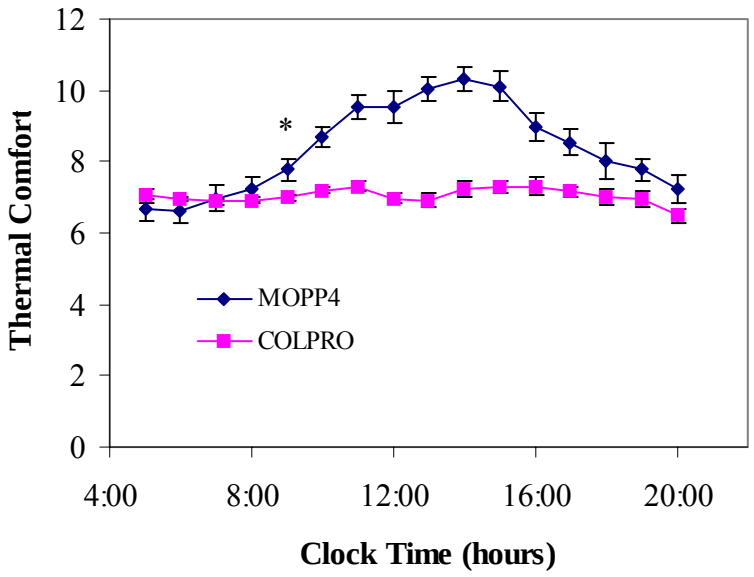

Figure 4. Mean ± see Thermal Comfort of Soldiers in the Individual Protective Ensemble (IPE – MOPP4) condition compared to the Collective Protection tents (COLPRO). * MOPP 4 significantly different from COLPRO from 9:00 hours and onward.

Fatigue Index

The IPE condition was rated as being more tiring and fatiguing compared to the COLPRO (Figure 5).

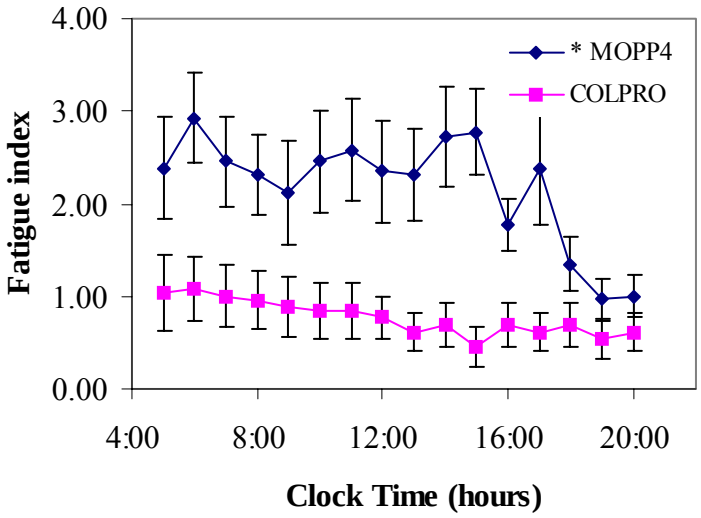

Figure 5. Mean ± see Fatigue Index of Soldiers in the Individual Protective Ensemble (IPE – MOPP 4) condition compared to the Collective Protection tents (COLPRO).* MOPP 4 significantly different from COLPRO.

Perceived Mental Effort
The perceived mental effort for the various CP duties remained similar in both conditions throughout the trials (Figure 6).

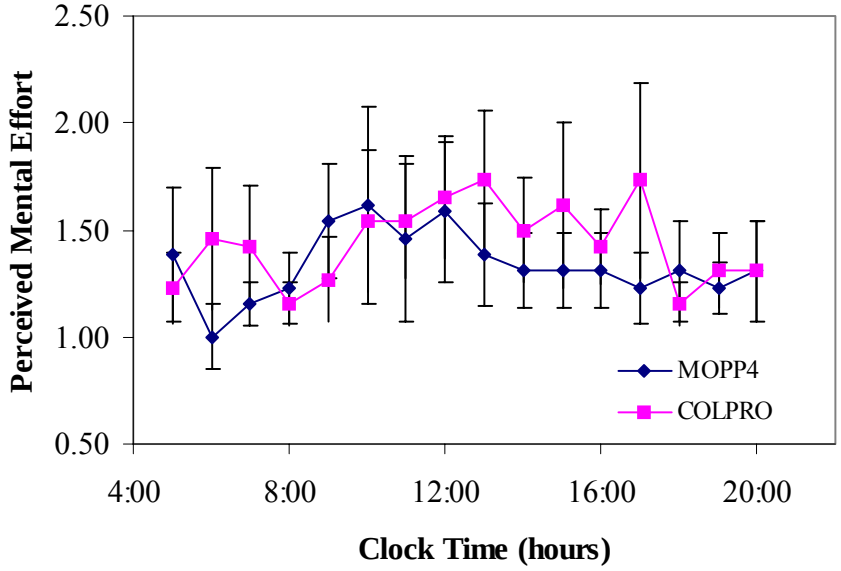

Figure 6. Mean ± see Perceived Mental Effort (PME) of Soldiers in the Individual Protective Ensemble (IPE – MOPP 4) condition compared to the Protection Protective tents (COLPRO).

Discussion

The purpose of this study was to examine the physiological and psychological effects of performing command post duties in two different protective systems that protect against chemical threats. One environment had the soldier encapsulated in a protective suite while the other environment had the soldier protected in an air-conditioned, temperature controlled tent. It is no surprise that the COLPRO - tent environment - was rated to be more favourable, efficient and less stressful. Nevertheless the soldiers were still able to work in the IPE MOPP 4 environment without incurring much of a change in body core temperature, which is usually a prime limiting physiological factor.

Rakaczky (23) proposed that the extent of performance degradation due to heat stress while in MOPP 4 is dependent upon 6 factors: type and combinations of environmental and protective ensemble worn; prevailing environmental conditions; duration during which a specific ensemble is worn; work intensity sustained; physical state of personnel; and the degree to

which the unit is trained in wearing protective clothing. Based on this list, we can assume that the comfortable environmental temperature, mean temperature (mean of 22°C), and the very light CP duties, (work intensity around 100 Watts), enabled the soldiers to work in the IPE ensemble for 24 hours without experiencing excessive increases in core temperature. From McLellan et al. study (18) it would be predicted that the soldier would be able to work indefinitely as long as they are not suffering from dehydration problems.

The present study is not the only one conducted over a 24-hour period that examines the effect of wearing IPE at a MOPP 4 level on performance. Posen et al (22), working with soldiers in a mechanized infantry squad, reported no performance degradation while wearing MOPP 4. Their study had 2 phases: phase 1 was a 60 hour trial in MOPP 4 with the 35 soldiers being in a 6 hours/1 hour cycle i.e., 6 hours in MOPP 4 and 1 hour out, until the 60 hours was complete. Phase 2 was a continuous 38-hour trial in MOPP 4. In this latter phase 26 soldiers were involved. Posen et al (22) reported environmental temperatures ranging from 20°C in the mornings to 27°C in the afternoon and work levels being very light to light depending on whether the soldier was in or dismounted from the tank.

The relatively cool environment observed in the present study as well as in the study of Posen et al. (22) produced minimal rises in core temperature during light activity while in MOPP 4, but did produced significant elevations in heart rate. This significant rise in heart rate while in MOPP 4 compared to a control environment (COLPRO MOPP 0 – i.e. wearing fatigues only) is typical and has been noted previously by others (1, 2, 17, 18). The rise in heart rate is mainly a cardiovascular response to an increased blood flow and fluid distribution to the surface of the body to promote body cooling by evaporation. This sweat loss to the environment is an important issue and water loss rather than core temperature may be a limiting factor in a comfortable environment (~ 20°C) when working in MOPP 4. Rich (24) supports this finding. From his mathematical model used to analyse US guidelines for wearing MOPP 4, he concluded that the guidelines were inadequate for continuous work. Rich used an arterial blood temperature of 39°C and /or an absolute body water loss of 3 litres as limiting factors during heat stress. He stressed that in all work loads at low to moderate temperatures, water loss (sweat loss) rather than core temperature may be the limiting factor.

In the present study it appears that the soldiers are in a compensable situation because their bodies are able to thermoregulate effectively. However, from Figure 3 it can be noted that despite the ≈ 1 litre increase in fluid intake, while in the IPE condition, the soldiers still lost on average 0.5 kg during the 24–hr period. If this fluid deficit is allowed to continue, by day six the soldiers would have reached the 3 litre water loss limit suggested by Rich (24), which would put the soldiers in a severe heat stress situation.

Fluid replacement during exercise in compensable heat stress conditions is critical and studies have shown its benefits i.e., lower heart rates and core temperatures, lower rates of heat storage and thus longer work tolerance (8, 15, 19, 21). The idea that soldiers do not drink enough when in MOPP 4 or in a field environment is not new, as others have reported a similar finding (3, 11, 25). Williams et al. (28) state that a 1.8 % loss of body weight in the form of water impaired exercise endurance. Thus, it cannot be stressed enough how insipid water loss can be in the MOPP 4 environment and how critical it is to maintain hydration for optimal physical and mental performance.

There is another physical limitation, which is often overlooked but constantly observed whenever the MOPP 4 ensemble is worn. That physical limitation deals with hand swelling, which occurred in all of our subjects. The soldiers commented on this effect during the debriefing session. They did not say that the gloves were too tight. This swelling may be related to the elevated hand blood circulation required for thermoregulatory purpose and impeded by the rubber gloves. How much this affected their duties and how to alleviate this problem has yet to be investigated.

From the psychological measures, two of the three indexes, i.e., fatigue index and thermal comfort, showed a significant difference between the IPE and COLPRO. The IPE was rated as being more thermally stressful and fatiguing. Values of 11 and 12 "almost as hot as I can stand" were reported by 7 of the 14 subjects while in IPE condition. Furthermore, 4 of the 14 subjects reported severe headaches, 1 of the 4 subjects was sick and 1 of the 4 subjects removed herself from the trial. Aside from the cumbersome nature of the IPE, which limits efficiency, the headaches and nausea reported from the soldiers were limiting factors in their ability to function. This is almost a 30% casualty rate after only 24 hours in IPE performing very light activities. This highlights the stressful nature of the IPE compared to the COLPRO even when the IPE was worn in a comfortable condition as occurred in this study.

It is interesting to note that although the study by Posen et al. (22) reported only minimal changes in core temperature of 0.5°C and minimal performance degradation, it was only for those individuals that were able to finish the allotted time for which the minimal degradation of performance applies. Of the 35 individuals in phase 1 trial, 6 did not complete the 60-hour trial and of the six, 4 reported dizziness and nausea as being the reasons for ceasing to do the trials. During phase 1 of the study by Posen et al. (22), it must be remembered that the soldiers were out of the IPE for 1 hour in every 6 hours of the trials. In phase 2 with 38 hours of continuous wearing of IPE, 14 of the 26 did not finish the trial and again nausea and dizziness were reported as the main reasons for ceasing the activity. This indicates that there were severe limitations to working in IPE beyond 24 hours especially if no relief is given to the subjects by removing the mask and unzipping the suit. Although heat was an important stressor, Posen et al. (22) suggest that respiratory distress may be the reason leading to nausea and headaches in the comfortable ambient environment. This hypothesis needs further investigation.

It is of some interest to note that the reports of major discomfort came after 13 - 16 hours in the IPE in both the present study and the study of Posen et al. (22). This is longer than the 9-10 hours that artillery soldiers reported that they might realistically be able to perform in MOPP 4 in a cool environment (20). The difference can be explained by the greater physical demand required by the artillery soldiers to perform their duties compared to the command post duties performed by the soldiers in the present study. Nemetz et al. (20) also reported that training in MOPP 4 is critical to optimize tolerance time. Training would acclimatize the soldiers both physically and mentally to this environment and thus reduce the time to perform normal duties. This comment is applicable to the present study, as the 4 soldiers who reported incidences of dizziness and nausea had no previous IPE experience.

In conclusion it can be said that the IPE environment was more stressful and fatiguing compared to the COLPRO environment and produced an approximate 30% casualty rate. Although core temperature showed minimal changes, heart rate, thermal comfort and the

fatigue indexes were significantly higher and highlighted the stressful conditions the soldiers were in while wearing IPE even in a comfortable environment.

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Annex A

Perceived Thermal Comfort Scale

1 So cold I am Helpless

2 Numb with cold

3 Very cold

4 Cold

5 Uncomfortably cold

6 Cool but fairly comfortable

7 Comfortable

8 Warm but fairly comfortable

9 Uncomfortably warm

10 Hot

11 Very hot

12 Almost as hot as I can stand

13 So hot I am sick and nauseated

Annex B

Fatigue Index Scale

0 **Not tired**

1 Barely tired

2 Slightly tired

3 Moderately tired

4

5 Tired

6

7 Very tired

8

9 Very very tired

10 Extremely tired

Annex C

Perceived Mental Effort

1 **LOW (EASY, SIMPLE)**

2

3

4

5 ----------

6

7

8

9

10 HIGH (DEMANDING, COMPLEX)

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3. TITLE (The complete document title as indicated on the title page. Its classification is indicated by the appropriate abbreviation (S, C, R, or U) in parenthesis at the end of the title)

Physiological and psychological effects of working in COLPRO compared to IPE in command post personnel (U)
Effets physiologiques et psychologiques de la protection collective (COLPRO) par rapport à la protection individuelle (EPI) sur les titulaires d'un poste de commandement

4. AUTHORS (First name, middle initial and last name. If military, show rank, e.g. Maj. John E. Doe.)

Michel B. Ducharme; Douglas G. Bell; Eric Drolet; Stephen Boyne

5. DATE OF PUBLICATION
(Month and year of publication of document.)

December 2004

6a NO. OF PAGES
(Total containing information, including Annexes, Appendices, etc.)

30

6b. NO. OF REFS
(Total cited in document.)

28

7. DESCRIPTIVE NOTES (The category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

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10a. ORIGINATOR'S DOCUMENT NUMBER (The official document number by which the document is identified by the originating activity. This number must be unique to this document)

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(U) Purpose: The purpose of this study was to examine the physiological and psychological effects of working in two different environments that protect against chemical threats. Methods: Fourteen (9 male and 5 female) regular Canadian Forces personnel were divided into two groups and performed various command post (CP) duties in a chemical threat scenario environment while wearing individual protective ensemble (IPE) or in a collective protective facility (COLPRO) for 24 hours. Each group performed CP duties in each environment and had a 24 hour rest between each trial. During their trials, core temperature was recorded and measured by a radio pill system; heart rate (HR) was recorded and measured using polar technology, body water loss was evaluated by body weight changes, thermal comfort, feeling of fatigue and perceived mental effort were evaluated using index scales. Results: core temperature was slightly elevated in the IPE compared to COLPRO by 0.2°C. Average 24hr HR was significantly elevated by 8 beats. Dehydration was significantly increased in the IPE environment; whereas, in the CLOPRO soldiers were able to maintain hydration status. Thermal comfort and fatigue ratings were significantly worse in the IPE (warmer and more fatiguing) compared to the CLOPRO. Mental effort to do the various CP duties was similar in both environments. Four of 14 soldiers while in IPE had severe headaches and one of the four was sick and one withdrew from the trial. This translated into a 28% casualty rate. Conclusions: It was concluded that even though core temperature was stabilized at a slightly higher level in IPE, this environment was more stressful than in COLPRO and led to inefficiencies.

(U) Objet : L'étude visait à déterminer les effets physiologiques et psychologiques du travail accompli dans deux contextes distincts qui assurent une protection contre les menaces chimiques.
Méthodes : Quatorze militaires des Forces canadiennes (Force régulière) (9 hommes et 5 femmes) ont été divisés en deux groupes et affectés à diverses fonctions rattachées à un poste de commandement (PC) dans le cadre d'une simulation de menace chimique. Les sujets ont soit porté un équipement de protection individuelle (EPI) soit évolué dans une installation de protection collective (COLPRO) pendant 24 heures. Chaque groupe a exécuté des fonctions d'un PC dans chaque contexte et bénéficié d'une période de repos de 24 heures entre chaque essai. Au cours des essais, la température centrale de chaque participant a été enregistrée et mesurée au moyen d'une capsule télémétrique; la fréquence cardiaque (FC) a été enregistrée et mesurée au moyen de la technologie polaire; la perte d'eau corporelle a été évaluée au moyen des changements de poids corporel; le confort thermique, la fatigue et l'effort mental perçu ont été mesurés à l'aide d'échelles. Résultats : La température centrale était légèrement plus élevée (de 0,2°C) dans le cas d'une protection individuelle (EPI) que dans le cas d'une protection collective (COLPRO). La FC moyenne sur 24 heures était nettement plus élevée (de 8 battements à la minute)1. La déshydratation était sensiblement plus importante dans un contexte de protection individuelle, alors que dans un contexte de protection collective, les militaires ont pu maintenir leur équilibre hydrique interne. Sur les plans du confort thermique et de la fatigue, les militaires bénéficiant d'un EPI étaient nettement moins avantagés (sensation de chaleur et de fatigue plus grande) que les autres. Quant à l'effort mental requis pour l'accomplissement des diverses fonctions associées à un PC, il était comparable dans les deux contextes. Quatre des quatorze militaires portant un EPI ont souffert de céphalées intenses; un des quatre est tombé malade et un autre a abandonné l'expérience. Autrement dit, l'essai s'est soldé par un taux de pertes de 28 %. Conclusions : Il ressort de

l'expérience que même si la température centrale s'est stabilisée à un niveau légèrement plus élevé en cas de port d'un EPI, ce contexte a engendré plus de stress que le mécanisme de protection collective (COLPRO) et a entraîné des pertes d'efficacité.

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