Effect of protective chemical garmenting on physiological strain index

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Abstract

Aims: The aim of this study was to examine the effect of physical activity with NBC protective clothing and military uniforms on physiological strain index (PSI).

Methods: The sample of this semi experimental study was consisted of thirty healthy male students or soldiers who were 18-25 years old. Their general health status had been assessed and they completed the informed consent form. They did physical activity according to Bruce protocol on treadmill with the use of random allocation for the priority of the use of coatings. Hemodynamic variables were measured and recorded before, after and five minutes after physical activity. After the end of physical activity, physiological stress index was calculated using heart rate and body core temperature rate. Data were analyzed using SPSS 11.5 software and repeated measure ANOVA and paired T tests.

Results: PSI (Physiologic Strain Index) for volunteers who were used chemical protective clothing and military uniform was 5.3±1.4 and 2.32±0.42, respectively (p<0.001). Homodynamic parameters demonstrated statistically significant difference after physical activity in two types of coverage (p<0.001). Amounts of physical activity time and distance were better in subjects who were used military uniforms than protective clothing (p<0.001).

Conclusion: NBC protective clothing can cause more physiologic strain, more limitation in performance and early exhaustion than the military uniforms. Using NBC protective clothing causes the increase of body core temperature, decrease of individual’s tolerance time and heat strain.

Keywords: NBC Protective Clothing, Physiologic Strain Index (PSI), Heat Strain, Hemodynamic Parameters

Introduction

During the Iran-Iraq war, for five years (1983-1988), Iraq's chemical attacks against Iranian forces and even Iraqi nationals, like the attack in Hoor al Hoveyzeh (1983), chemical bombarding in Sardasht (1981) [1], and finally the tragedy of chemical bombardment of the ordinary people in Halabja (1367), with more than five thousand martyrs and seven thousand wounded victims [2, 3], have been the horrific atrocities in the human history.

Chemical weapons, such as mustard gas, have direct cutaneous, mucosal or inhalatory harmful effects on all body tissues that some of them are fatal, and some others cause persistent and chronic complications on individual. Therefore it is necessary to design and prepare some required protective or defensive tools in prediction of the exposure to chemical attacks or industrial chemical accidents. On the other hand, in many jobs or military conditions, in order to prevent physical, chemical and environmental injuries, people have to use protective clothes. Since these clothes should be used in the operating conditions and activities such as combat or relief and rescue, they should exert the least physiological, mental, and the ergonomic limitations on the body despite the protective function. For example, the selective property of this coverage in providing the one-way flow of air and heat from inside to outside or refining of the toxic substances from the outside into the inside of the cover is important.

When using the unusual coverage, climate conditions like hot and humid weather or physical and body activity interfering with the metabolic heat exchange and regulation inside the body with external environment, change the level of individual tolerance toward the activity [4].

When using protective clothing, the body's insulation feature is increased and the sweat evaporation is decreased, thus the individual suffers by losing the ability to repel the body heat. Especially the use of non-penetrable clothes increases this inability. In this case, there is the risk of fatal heat shock within an hour [1]. When wearing the protective clothes in the warm environments, the loss of water and electrolyte through sweating causes health and the ergonomic problems [5]. From 1966 to 1979, the center for disease control in the United States had reported 6864 cases of death resulted from heat imposition on job condition. Military personnel, firemen and relief
personnel are required to use anti-fire anti-smoke and anti-chemicals equipment and covers. These people are considered as the victims of heat stress and its effect on physiological activities. Starting of the damages caused by heat are gradual, and the victim is suddenly trapped [6].

During recent decades, a large number of researchers have attempted to evaluate these clothes and finding all necessary standards in this field [7, 8]. It seems that to protect the military forces against chemical agents, the most effective tool is to use special chemical, biological and nuclear clothing along with the mask [9]. The variety of protective clothing products especially anti-chemical garmenting (NBC) is high. Countries like the United States, Germany, Britain and Iran are able to produce this type of clothing; therefore, the evaluation of the function and effect of these clothing on the body is important. The knowledge of this impact causes the making of appropriate decisions in the operational use of this type of clothing.

This study was conducted to determine the effect of NBC protective clothing produced by Milad production compared to the usual combat uniform on the physiologic strain index (PSI).

**Methods**

This research is a quasi-experimental concurrent study. The required sample size was calculated by Cochrane's formula of sample size estimation (α=5%; β=20%) and came out to be at least 26 people. Accordingly, 30 student or soldier volunteers who had the study's inclusion criteria (no history of respiratory diseases, motor and kidney problems, having general health based on physical examinations, body mass index of 18 to 30, lack of continuous professional exercise or history of being a professional athlete and non-smoking) were selected and included in the study after explaining the aims and methods of implementing the physical activity and obtaining their informed consent. Transposition of the use of each cover (military clothes and NBC protective clothing) was randomly determined for each volunteer.

To conduct the research and based on the laboratory facilities, physical activities were designed and prepared. The lab setting was composed of two rooms with the conditions of stability in humidity and temperature. A room was used as the participant's preparation and rest room and the other was used installing a treadmill apparatus (TF 9950, Titan; Taiwan) as a place to perform physical activity and as the laboratory.

During the test, participants were only under the surveillance of the researcher and any environmental stimuli that would increase or decrease the activity's motivation was prevented. Moreover, to deal with any unexpected event, and also to accurate recording of data, the equipments needed for cardiac basic restoration were used, such as cardiac heart monitoring (TEMP 805O, W&S; USA), arterial blood oxygen saturation measuring device (Oxypleth; U.S. ), core body temperature control system through the ears (Microlife; United States), digital pressure gauge device (Microlife; United States), chronometer (Kenko; United States), military uniforms and NBC clothing (Milad; Iran), anti-chemical masks (MSA-11-1; United States) and the device for height and weight measuring (Seca; United States).

Data collecting tool was a three-part checklist to record demographic, physiologic and hemodynamic variables and feeling comfortable in the clothes. In addition, the checklist of the subjects' general health was developed according to the inclusion criteria and its content validity was confirmed based on the opinion of 10 professional experts. Reliability and validity of physiological data collection tools were analyzed and calibrated based on the standard proposed by the manufacturers of the equipments. Subject was resting after entering the research environment, initially for 5 minutes at room number one. The given hemodynamic and physiologic variables were recorded. After wearing clothes and shoes he/she was settled on the treadmill in order to perform body exercise. First, he/she was walking for 3 minutes and for body warm-up by speed of 2.74km/h and the inclination if 10 degrees. Then every 3 minutes, according to Bruce protocol of physical activity, the slope and speed of the system were increased. During physical activity, in spite of the continuing control of the heart rate and cardiac monitoring, participants were exposed under the direct observation of the researcher. Physical activity continued until the participant complained about or declared his/her inability to continue the activity or if heart rate was exceeded the predicted limit (220 minus the individual's age). Immediately after the end of exercise, at recovery mode, i.e., five minutes after finishing the activity, the given variables were measured and recorded. After completing these steps, the subject changed his/her clothing and after drinking left the test environment.

Physiological strain index (PSI) was calculated and reported according to the formula 5 (Tr-T0)/(39.5-Tr0)+5(HRi-HR0)/(180-HR0). In this formula, Tr0 and HR0 are respectively the core body temperature.
and heart rate before the physical activity and HRi and Tri are the core body temperature and heart rate after exercise [10, 11, 12]. A total of 60 tests were taken from the 30 volunteers participating in the study. The interval between the tests using the two clothing was at least 48 hours [13]. For data analysis, SPSS 11.5 software was used and to describe the data and to compare the physiological and hemodynamic responses in both coverage or clothing and three times of measurement, the repeated ANOVA was used and for comparing the mean indexes in the two groups, paired T test was used. Before using the parametric tests, the normal distribution of data was confirmed using Kolmogorov-Smirnov test.

**Results**

The average age of volunteers was 21.6±1.4 years (ranging from 20-25 years). The average height and weight of participants were 173.90±4.48cm and 67.72±5.93kg. The mean of body mass index of participants was 22.44±2.24 (ranging from 19.2-29.2). The mean temperature and humidity of testing environment during the test with the ordinary cover were respectively 25.87±0.50 C and 68.10±6.54% and during the test with chemical garments were 26.0±0.26 C and 67.67±5.73%. There was no statistical significant difference between the temperature and humidity of the test environment when conducting physical activity using the two clothing.

The difference between the Physiological strain index (PSI) between groups and at different stages was significant (p<0.001; Table 1).

<table>
<thead>
<tr>
<th>Clothing type→Variable↓</th>
<th>Military uniform</th>
<th>Chemical garment</th>
<th>Level of significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central or core temperature</td>
<td>37.99±0.39</td>
<td>38.89±0.33</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Heart rate (HR)</td>
<td>128.1±10.63</td>
<td>135.60±15.26</td>
<td>0.060</td>
</tr>
<tr>
<td>Respiratory rate (RR)</td>
<td>28.67±2.48</td>
<td>31.10±3.63</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Hemoglobin saturation</td>
<td>96.87±0.77</td>
<td>94.77±2.26</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Systolic blood pressure</td>
<td>145.13±8.17</td>
<td>146.37±11.06</td>
<td>0.877</td>
</tr>
<tr>
<td>Diastolic blood pressure</td>
<td>68.20±7.28</td>
<td>88.60±12.86</td>
<td>0.390</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Clothing type→Variable↓</th>
<th>Military uniform</th>
<th>Chemical garment</th>
<th>Level of significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central or core temperature</td>
<td>37.68±0.43</td>
<td>38.59±0.32</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Heart rate (HR)</td>
<td>98.33±7.95</td>
<td>96.03±10.17</td>
<td>0.289</td>
</tr>
<tr>
<td>Respiratory rate (RR)</td>
<td>17.70±1.93</td>
<td>18.97±1.97</td>
<td>0.506</td>
</tr>
<tr>
<td>Hemoglobin saturation</td>
<td>96.93±0.86</td>
<td>96.70±0.95</td>
<td>0.388</td>
</tr>
<tr>
<td>Systolic blood pressure</td>
<td>120.83±7.35</td>
<td>119.37±8.47</td>
<td>0.654</td>
</tr>
<tr>
<td>Diastolic blood pressure</td>
<td>76.93±7.16</td>
<td>77.23±7.63</td>
<td>0.970</td>
</tr>
</tbody>
</table>

The comparison of the average hemodynamic parameters before the beginning of the physical activity had not significant difference in the two groups (Table 2), but the parameter of the central temperature and respiration rate as an increase and the arterial blood oxygen's saturation of hemoglobin showed a significant decrease (p<0.001) in the NBC protective clothing group (Table 3).

![Table 1](image1)

![Table 2](image2)

![Table 3](image3)

![Table 4](image4)

![Table 5](image5)
Effect of protective chemical clothing on physiological strain index

Within five minutes after physical activity, the rate of core temperature in the NBC protective clothing group showed a significant increase (p<0.001) compared to the military clothing (Table 4). Central temperature's difference in the NBC protective clothing in three previous stages, immediately and 5 minutes after the activity was significant (p<0.001; Table 5). Also there were some significant changes in the central temperature (p<0.001) in the military clothing group (Table 6).

Table 6- The comparison of the hemodynamic parameters at three different stages in participants with military clothing (ANOVA test)

<table>
<thead>
<tr>
<th>Clothing type Variable</th>
<th>Before the activity</th>
<th>After the activity</th>
<th>Recovery</th>
<th>Level of significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central or core temperature</td>
<td>36.9±0.34</td>
<td>37.99±0.39</td>
<td>37.68±0.43</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Heart rate (HR)</td>
<td>74.9±0.9</td>
<td>128.13±10.63</td>
<td>98.3±7.95</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Respiratory rate (RR)</td>
<td>14.77±1.16</td>
<td>28.67±2.48</td>
<td>17.70±1.93</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Hemoglobin saturation</td>
<td>97.27±0.87</td>
<td>96.87±0.77</td>
<td>96.93±0.86</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Systolic blood pressure</td>
<td>117.70±9.90</td>
<td>145.13±8.17</td>
<td>120.83±7.35</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Diastolic blood pressure</td>
<td>79.60±6.15</td>
<td>68.20±70.28</td>
<td>76.9±7.16</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Discussion

In both of studied groups, at the post physical activity stage, physiological strain index (PSI) increased. Calculation of this index, on the basis of formula was the function of changes in the core temperature and heart rate. Hemodynamic results represent the significant increase of these two variables, along with changes in other variables. During recovery (five minutes after the end of activity), by reduction of the given two hemodynamic parameters, physiological strain index (PSI) also decreased, but did not reach the basic and primary level. On the other hand, at the end of recovery period, in the NBC protective clothing, physiological strain declined with less speed compared to the uniform. There was no statistically significant difference in environment in terms of temperature and humidity and in the research subjects, in terms of hemodynamic parameters of both types of clothing. Therefore, the effect of these variables on the findings of the study has been controlled.

However, it has been shown in the other studies that wearing the NBC cloth in the warm environment decreases the tolerance time toward the activity [14]; however, some studies have also mentioned even the effect of NBC protective clothing without a mask, on the amount of activity tolerance in comparison with the common combat clothing [4]. By wearing of NBC clothing and beginning of the activity especially in hot weather, body will start sweating. This wetness and saturation of the cloth will change its thermal characteristics. Therefore, NBC clothing, with regard to the increase in the metabolism rate and decrease in the evaporative efficiency, are causing the rate of heat dissipation to be inefficient, and increase the body heat storage. Thus, this clothing can even despite light to moderate activity, especially in hot weather, cause thermal strain for the individual [8]. Although some researchers believe, according to their studies, that perhaps the cause of reduced tolerance to activity during the use of NBC protective clothing is not multifactorial physiological agent [15]; but it seems that, considering the changes in the central temperature, heart rate and respiratory rate (increase in respiratory work), when using this type of coverage, one should take the various physiological factors into consideration. Obviously, according to these results, the causative or transposition relationship of any of these factors cannot be investigated. But they believe that wearing the protective clothing increases dehydration due to the increased heat storage and increased central temperature and thus the increased rate of sweating. In dehydration conditions, the blood volume reduces and its osmolarity increases. Decreased blood volume causes the sweating rate to decrease and thus the body temperature will increase. Meanwhile, to compensate for pressure loss, the skin blood flow filling is reduced; therefore, the central heat transferring to skin is reduced and central temperature is increased [16]. However, some studies show the increased sweating when using the NBC protective clothing [14, 17].

It is noteworthy that during the recovery period, the central temperature in combat uniform decreases more rapidly and approaches to the baseline threshold. It appears that, in addition to changes in the internal system of core body temperature regulation due to the possible changes in body fluid volume or amount of sweating, the ability of NBC protective clothing layers in the heat exchange should be taken into consideration. None of the conducted studies have mentioned the possible differences between the skin and internal and external layer of NBC protective clothing. The study of this difference can explain the exchanging role of layers. In the products of the other countries such as Germany, the incidence of these changes has been reported similarly [17]. It is
suggested that by improving or changing the Milad production's technology of NBC protective clothing, the conditions for the exchange of core body temperature with the environment be provided.

Conclusion
Milad’s NBC protective clothing causes more physiological strain, further restrictions in the performance and earlier fatigue in the individual compared to the military uniform. In addition, increasing of the core body temperature causes the reduction of individual's tolerance time and heat stress while using NBC protective clothing.

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References