Original Article

COMPARING THE EFFECT OF FIRE-FIGHTING PROTECTIVE CLOTHES AND USUAL WORK CLOTHES ON AEROBIC CAPACITY (Vo2max)

Majid Najafi Kalyani[1], Abbas Ebadi[2], Soheil Najafi Mehri[3], Nahid Jamshidi[4]

ABSTRACT

Objective: In many jobs, people must use protective clothes to avoid physical, chemical and environmental damages. Such clothes should cause the minimal physiological, mental and organic limitations on the body, beside their protective features. The aim of this study was to compare the Iranian fire-fighting protective clothes with usual work clothes, in terms of their effects on Aerobic capacity of the subjects.

Methodology: This is an experimental study, in which 30 healthy male participants were chosen according to inclusion criteria. Their physical activity was measured once by wearing Fire-fighting protective clothes and the other time by wearing usual work clothes by randomly, based on Bruce protocol. After the physical activity, parameters such as activity time, and the distance were measured. Aerobic capacity was also predicted by setting the activity time in the Bruce formula.

Results: The results show that the aerobic capacity (Vo2max) was44.25±6.42ml/kg/min in participants with fire-fighting protective clothes, While this number was 57.43±5.34 ml/kg/min for usual work clothes. This difference is statistically significant ($p<0.001$). These two sets of clothes are different in their effects on parameters such as activity (exhaustion), the distance and Vo2max.The obtained values for common clothes are better than for fire-fighting protective clothes.

Conclusions: The results showed that Iranian fire-fighting protective clothes result in less tolerance time, because the aerobic capacity (Vo2max) for these clothes was observed as less than the usual work clothes.

KEY WORDS: Fire-fighting protective clothes, Usual work clothes, Aerobic capacity, Bruce protocol.

Pak J Med Sci October - December 2008 (Part-I) Vol. 24 No. 5 678-683

How to cite this article:

Kalyani MN, Ebadi A, Mehri SN, Jamshidi N. Comparing the effect of Fire-fighting protective clothes & usual work clothes on aerobic capacity (VO2max). Pak J Med Sci 2008;24(5):678-83.

Correspondence

Majid Najafi Kalyani, MSN.
Department of Medical Surgical,
Faculty of Nursing,
Army University of Medical Sciences,
Tehran, Iran.
E-mail: majidnajafi5@yahoo.com

* Received for Publication: January 23, 2008
* Revision Received: January 26, 2008
* 2nd Revision Received: June 17, 2008
* Final revision Accepted: July 25, 2008

INTRODUCTION

In many jobs, people must use protective clothes to avoid physical, chemical and environmental damages. Such clothes should cause minimal physiological , mental , and organic limitations on the body, beside the protective feature.[1,2] Center of disease control has reported 6864 death because of high temperature in working condition from 1966 to 1979.[3] The increasing use of heavy and impenetrable

clothes at work discloses the harmful effects of temperature on body. In 1994, the army air force of the U.S. declared that 19 forces have been hospitalized due to their exposure to heat while doing the activity. During this year, the army hospitalized 196 people because of heat stress and the resulting diseases.[4] People working at fire station and the assistants are required to use clothes that are resistant to fire, smoke and chemical materials. These people are called victims of heat stress on physiological activities. Starting damage due to heat is gradual and the individual is affected by them suddenly.[3] When a person uses protective clothes, he has some activities at the same time, When a person uses these clothes in critical conditions, he has to do hard and heavy activities while he must tolerate the clothes to protect himself against physical and chemical dangers.[5] In the recent decades , researchers have done a lot regarding evaluating these clothes and finding some standards for them.[6,7] Despite many investigations done on these clothes , giving a general guideline for using these clothes is difficult , because the investigations are complex due to different kinds of protective clothes, the differences among the participants and different physical protocols.[8]

Physical activity of an individual is related to his aerobic capacities. In critical situations, like fire, a person has to use protective clothes during physical activity. So, it is necessary to minimize the interfering causes in the waste of energy in order to maximize the energy and power of that person. Can fire-fighting protective clothes be assumed as interfering causes in comparison with usual work clothes? Determining the aerobic capacity changes in different environmental situations and different clothes of people are used as an indicator in predicting people's health and efficiency status. So, by using Vo2max criterion as indicator determining the aerobic capacity, the effect of these two kinds of clothes on aerobic capacity (Vo2max) and tolerance was investigated, comparing Iranian protective clothing with usual work clothes.

METHODOLOGY

This was an experimental study. Sampling method was according to purpose and based on inclusion criteria from the research society. Participants (30 young male) were selected based on their willingness. Their selection criteria were good general health, according to health status check list, no heart disease, respiratory, renal, anemia and diabetic history, and without any professional athletic history. They were also, without any injury, and smoking history. They were 18 to 25 years old all males and within the determined range of body mass index (19.2 – 29.2). Each person had done the investigatory protocol on treadmill TF 9990 manufactured in Taiwan's titan factory, by wearing randomly fire-fighting protective clothes and common clothes with interval at least 48hour.[1,6] In selecting clothes, their apparent differences were also considered, so the usual work clothes were used which were similar to fire-fighting clothes in terms of color and pattern, in order to eliminate the by psychological bias. The study conditions included two room equipped with required laboratorial instruments. In room one after five minute rest, the primary parameters such as height, weight (using Seca machinery), age, body mass index(formula for this index was person's weight over squared height) and also homodynamic and physiological parameters including blood pressure (microlife machinery), heart rate (S&W machinery model temp 8680) and respiratory rate were measured.

The heat and humidity levels of the laboratory environment were measured by thermometer and hygrometer. After measuring all recording, the required parameters and wearing the clothes, the person was shifted to room two and setting the treadmill. First, he walked slowly by the speed of 2.74 km/h and 10 degree slope for warm up. After every three minutes, speed and slope of treadmill increased according to Table-I.[9] the study time was done during month of August and randomly in specific hours of the day. The criterion for stopping the test was the participant's fatigue or

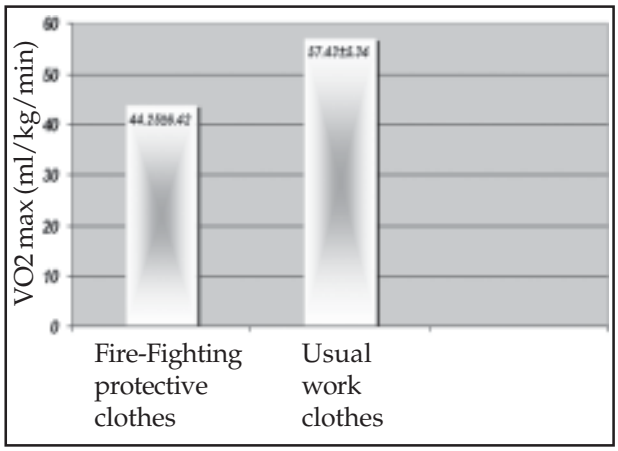

Fig-1: Comparison of aerobic capacity in usual work clothes and fire-fighting protective clothes.

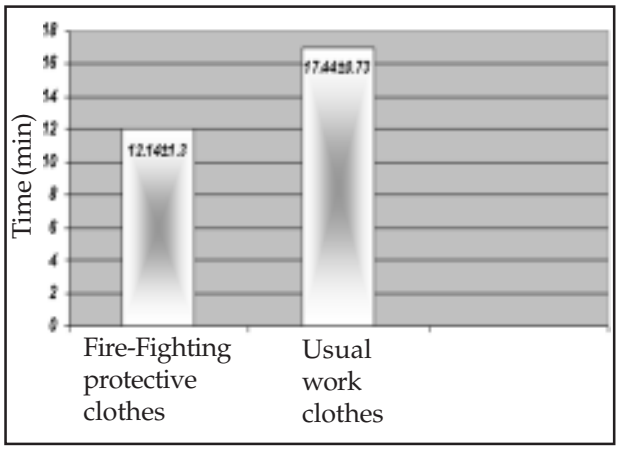

Fig-2: Comparison of Activity time in usual work clothes and fire-fighting protective clothes.

increasing his heart rate beyond the expected maximum, according to relation age - 220.[10] The physical activity protocol in this study was Bruce protocol which was a way for participants of 20 – 29 years old.[10]

After stopping physical activity (due to person's fatigue or his heart rate more than the expected maximum according to relation of age – 220), the distance and time of his protocol performance were recorded. Using the following formula, Vo2max was predicted as the aerobic capacity index:

$$Vo2max = 14.8–(1.37\times t)+(0.457\times t^2) - (0.012\times t^3)$$

In this formula, t is the activity time in Bruce protocol.

Data were analyzed by SPSS version 11.5. The results were reported as standard deviation ±mean (SD±Mean). To compare the means of two clothes, paired sample t-test was used. To investigate the relationship between Vo2max and the time of physical activity, Pearson's coefficient was used and also multiple linear regression for determining the kind of relationship.

RESULTS

The participant's features have been represented in Table-II. According to these result, the range of age 21.6±1.4 and mean of 22.44±2.24 BMI were under the investigation. Means of height and weight used in BMI survey were respectively 173.90±4.4cm and 67.72±5.93kg.

To investigate the participant's physiological and heomodynamic changes, the core temperature of body, heart rate, respiratory rate and blood pressure were measured. Before the test that did not show any statistically significant relation in both sets of Clothes ($p>0.05$). The results of study show that the predicted Vo2max in usual work clothes was 57.43±5.34 ml/kg/min and in fire-fighting protective clothes was 44.25±6.42ml/kg/minutes, so that this difference is statistically significant ($p<0.001$) Fig-1.

The activity time (fatigue time) of the participants in usual work clothes was 17.44±0.73 minutes and in fire-fighting protective clothes 12.14±1.3 minutes, which was statistically significant ($p<0.001$) Fig-2.

The distance by common clothes was 1628.6±226.9 m which is significantly more than the distance by fire-fighting protective clothes (1041.73±152.69 m, $p<0.001$). Using the activity time in usual work clothes and fire-fighting protective clothes and using multiple linear regression tests, all quantitative parameters were included in the study to investigate their effects on aerobic capacity (Vo2max). the following formula with 99% accuracy and by only using activity time predict the Vo2max for usual work clothes and fire-fighting protective clothes which are simpler and shorter than Bruce formula for predicting aerobic capacity (Vo2max) Fig-3.

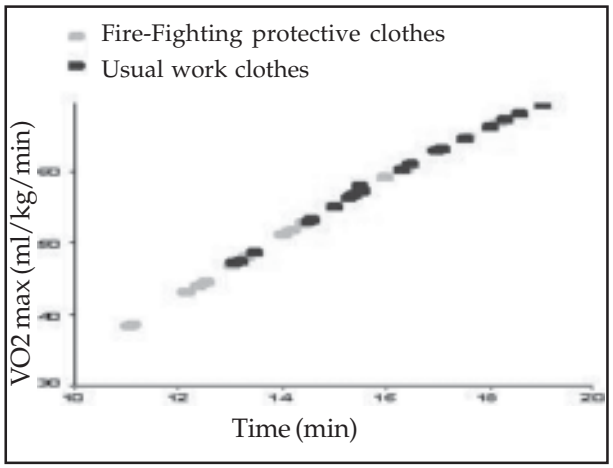

Fig-3: Regression relationship between activity time and Vo2max in usual work clothes and fire-fighting protective clothe.
VO2max (usual work clothes) = -1.381+time (3.748) (R =99%, P<0.001)
VO2max (Fire-fighting clothes) = -5.145+time (3.992) (R =99%, P<0.001)

VO2max (Usual work clothes) = -1.381+time (3.748) (R =99%, P<0.001)
VO2max (Fire-fighting clothes) = -5.145+time (3.992) (R =99%, P<0.001)

The obtained regression showed that by using this relationship and under the same conditions, Vo2max is predictable for every separate clothes comparing Bruce formula.

DISCUSSION

Vo2max is considered as a criterion for determining aerobic capacity and people's tolerance time.[11] in this study, the predicted Vo2max in the group using fire-fighting protective clothes was significantly less than the group with usual work clothes. In practical terms what it is mean that, the person are likely to get tired soon. Mcllelan showed that in the Canadian chemical protective clothes, Vo2max was significantly less than usual work clothes.[12] The result of our study with subjects wearing Iranian fire-fighting protective clothes are similar to these finding and show that protective clothes cause decrease in person's tolerance and Vo2max.

Some researchers did not introduce any specific physiological parameters on fatigue span while doing activity, and stated various physiological and psychological factors.[13] But Heat storage in body and core temperature increase due to decrease in heat dissipation and this cause the earlier fatigue decrease in Vo2max.[14,15]

The significant increase in the body temperature of the group with protective clothes in comparison with the other group shows this

Table-I: Participants' activity on treadmill based on Bruce protocol

Slope (grade)	*Speed (km/hr)*	*Time (min)*	*Stage*
10	2.74	0	1
12	4.02	3	2
14	5.47	6	3
16	6.76	9	4
18	8.05	12	5
20*	8.85	15	6
22	9.65	18	7
24	10.46	21	8
26	11.26	24	9
28	12.07	27	10

Maximum time the participants continued the protocol*

Table-II: Subjects demographics (n=30)

Statistic Variable	*Mean±SD*	*Maximum*	*Minimum*
Age(year)	21.6±1.4	25	20
Height(cm)	173.90±4.4	187	166
Weight(kg)	67.72±5.93	86	58
BMI	22.44±2.24	29.2	19.2

Table-III: Comparison of environment's temperature and humidity while doing the test in both sets of clothes

Variable Group	*Temperature (centigrade)*	*Humidity (%)*
	Mean±SD	*Mean±SD*
Usual work clothes	25.87±0.50	68.10±6.54
Fire fighting protective clothes	26.00±0.45	67.47±7.04

* No difference between temperature and humidity was see.

early fatigue, although weight of protective clothes can be the cause of earlier fatigue due to physical features and potential collection of sweat.[16] Weight of protective clothes is an important factor in cardio-pulmonary damages while using them,[7] but in our study, the clothes were not weighted.

Moreover, core temperature, perspiration and dehydration will increase. Therefore, blood pressure decrease and osmolarity increases, and causes peripheral blood flow and inspiration to decrease and all these lead to high temperature and decrease in tolerance span.[14,15] Goldman showed that tolerance time of protective clothes decrease by increasing environmental temperature.[17]

The result of this study showed that activity time in usual work clothes is significantly more than in fire-fighting protective clothes. In a study by Ghasemi et al, the same results have been obtained for fatigue span of military and chemical protective clothes.[6] Intensity and time of activity can also affect tolerance of people, so it is suggested that people using protective clothes do their activities slowly to increase their activity time. Distance for usual work clothes is significantly more than fire-fighting protective clothes. Aoyagi showed that the distance by usual work clothes is more than protective clothes ($p<0.05$). He concluded that wearing protective clothes in hot environments increase perspiration and cause decrease in blood volume and tolerance time.[15] the results of other studies show that suggesting a general guideline for protective clothes is difficult because of high difference in protective clothes and also different participants.[6, 18, 19]

In this study, to predict aerobic capacity (Vo2max) the following formula was used.

$$Vo2max = 14.8 - (1.37\times t) + (0.457\times t^2) - (0.012\times t^3)$$

Based on the kind of clothes and activity time, we obtained two formulas for predicting Vo2max which was easier and shorter than Bruce formula and requires only activity time parameter. Moreover, they are more reliable and accurate($R = 99\%$, $P<0.001$).

VO2max (usual work clothes) = -1.381+time (3.748) (R =99%, P<0.001)

VO2max (Fire-fighting clothes) = -5.145+time (3.992) (R =99%, P<0.001)

In summary the results showed that fire-fighting protective clothes have weaker results in cases such as activity time, distance, and fatigue time. The same result is correct in aerobic capacity which can be because of high weight, and thickness in comparison with usual work clothes. Based on the obtained results, it is suggested that heads and workers of fire station and unpredictable events to force using fire-fighting protective clothes the same as usual work clothes for a specific time to improve the physical capacity of individuals. It is also suggested to make all assistants familiar with these clothes limitations to avoid early fatigue and unfavorable results. Compatibility of individuals with these clothes in daily training can increase their ability in using these clothes and minimize fatigue span by increasing Vo2max.

Limitations of the study: It includes environment's heat and humidity effect that were controlled by choosing the same time span and a laboratory environment which had a relatively constant humidity. The parameter of body ability as a limitation also was controlled by comparing the person's participation in both groups and the criterion of not having professional sport history and body mass index for the whole group in the range of 19.2 to 29.2.

REFERENCES

1. Chenung SS, Mclellan TM, Tenaglia S. The thermophysiology of uncompensable heat stress. Sport Med 2000;2(5):329-59.
2. Holmer I. Protective clothing and Heat stress. Ergonomics 1995;38(1):166-82.
3. Centers for disease control and prevention. Heat related illness and death-missouri, 1998 and United States 1979-1986. Morbid mortal weekly rep1999;48:469-73.
4. Gardner JW, Amoros PJ, Grayson JK. Hospitalization due to injury. Inpatient medical records data. Mili Med 1998;164,5:1999.

5. Bishop P, Ray P, Reneavp. A review of the ergonomics of US military chemical protective clothing. Inter J Industrial Ergonomics 1995;15:271-83.
6. Ghasemi A, Asgari A, Farajzade A, Roozbahani A. Comparing the effect of Iranian and German chemical protective clothes on some physiological parameters of people. J Mil Med Spring 2005;(7):1-9.
7. Rissanen S, Rintamaki H. Thermal responses and physiological strain in men wearing impermeable and semi permeable protective clothing in the cold. Ergonomics 1997;40(2):141-50.
8. Sport fitness advisor. Bruce treadmill test.http://yahoo.com/Vo2max/Bruce protocol/html; 2006
9. MC Ardle WD, Katch FI, Katch VL. Exercise physiology. 5th edition. Lippincott Williams & Wilkins 2001;459-85.
10. Niavarani A, Medical physiology-Vol 1 – 10 ed, Samat publication. 2000;234-320.
11. Mclellan TM, Jacobs I, Brain JB. Influence of temperature and metaboolic rate on work performance with Canadian force NBC clothing. Ergonomics 1993;64(7):587-94.
12. Powers KS, Howley ET. Exercise physiology. Fifth ed. McGraw-Hill company 2004;296-302.
13. Mclellan TM, Jacobs I, Brain JB. Influence of temperature and metabolic rate on work performance with Canadian force NBC clothing. Ergonomics 1993;64(7):587-94.
14. Smith G, Bishop P, Ray P, Smith J. Physiological factors associated with premature work termination in protective clothing users. Inter J Indust Ergono 1994;13:147-55.
15. Sawka MN, Latzka WA, Montain SJ, Cadarette BS, Kolka MA, Krning KK, et al. Physiological tolerance to uncompensable heat, intermittent exercise, field vesus laboratory. Med Sci Sport Exerc 2001;33(3):22-430.
16. Goldman RF. Tolerance time for work in the heat when wearing CBR protective clothing. Military Medicine1963;128(8):778-6.
17. Aoyagi Y, Mcellan TM, Shephard RD. Effects of training and acclimation on heat tolerance in exercising men wearing protective clothing. Eur J Appl Physiol Occup Physiol 1994;68(3):234-45.
18. Constable SH, Bishop PA, Nunneley SA, Chen T. Intermittent microclimate cooling during rest increases work capacity and reduces heat stress. Ergonomics1994;37(2):277-85.
19. Najafi S, Najafi M, Ebadi A, Ghasemi A, Tayebi A, Hafezi S. Comparing the effect of military work clothes and milad NBC protective clothes without mask on maximal oxygen consumption. Kowsar Med J 2007;11(4):367-72.

Authors:

1. Majid Najafi Kalyani, MSN.
Department of Medical Surgical,
Faculty of Nursing,
Army University of Medical Sciences,
Tehran, Iran.
2. Abbas Ebadi, Instructor,
MSN, Ph.D Candidate,
Department of Medical Surgical,
Faculty of Nursing,
Tarbiat Modares University,
Baqiatallah Medical Sciences University,
Tehran, Iran.
3. Soheil Najafi Mehri, Instructor,
MSN, Ph.D Candidate,
Department of Medical Surgical,
Faculty of Nursing,
Baqiatallah Medical Sciences University,
Tehran, Iran.
4. Nahid Jamshidi, BSN,
MS Candidate of Nursing,
Razi Nursing Faculty,
Kerman Medical Sciences University,
Kerman, Iran.