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# Designing of the Cooling Vest from Paraffin Compounds and Evaluation of its Impact Under Laboratory Hot Conditions

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## ABSTRACT

**Background:** The phase change materials (PCMs) have the appropriate properties for controlling heat strain. One of the well-known PCMs is paraffin. This study aimed to design the cooling vest from the cheap commercial paraffin compound and evaluation of its effectiveness under laboratory hot conditions.

**Methods:** the cooling vest was made of the polyester fabric and it had 17 aluminum packs. The each of aluminum packs was filled by 135 g of prepared paraffin with a proper melting point in the range of 15–35°C. an experimental study was conducted on ten male students under warm conditions (air temperature = 40°C, relative humidity = 40%) in a climatic chamber. Each participant was tested without cooling vest and with cooling in two activities rate on treadmill to include: light (2.8 km/h) and moderate (4.8 km/h). The time of this test was 30 min in each stage. During the test, the heart rate, the oral temperature, the skin temperature were measured every 4 min. Finally, data were analyzed using the Kolmogrov–Smirnov and repeated measurement ANOVA test in SPSS 16.

**Results:** The latent heat of the prepared paraffin compound and the peak of the melting point were 108 kJ/kg and 30°C, respectively. The mean and standard deviation of heart rate, oral temperature, and skin temperature with cooling vest in light activity were 103.9 (12.12) beat/min, 36.77 (0.32)°C, and 31.01 (1.96)°C and in moderate activity were 109.5 (12.57) beat/min, 36.79 (0.20)°C, and 29.69 (2.23)°C, respectively. There is a significant difference between parameters with a cooling vest and without cooling ($P < 0.05$).

**Conclusions:** The designed cooling vest with low cost can be used to prevent thermal strain and to increase the physiological stability against the heat. However, the latent heat of this cooling vest was low.

**Keywords:** Cooling vest, heat strain, hot and dry conditions, paraffin

## INTRODUCTION

Heat is considered as one of the harmful agents in many workplaces. The heat exposure will initially create the heat strain but in long-term exposures, it will cause some problems such as muscle cramps, heat stroke, heat syncope, heat exhaustion, less productivity, more accident rate and less safety level in workplaces.[1,2] there are various strategies in the field of engineering and administrative

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controls To decrease heat strain.[3] The usage of personal cooling equipment is one of the strategies for decreasing heat strain in hot environments.[4] In general, cooling equipment can be divided into five groups: Evaporative cooling equipment, equipment based on phase change materials (PCMs), compressed air equipment, liquid circulation equipment, and thermoelectric equipment.[5] Among cooling equipment, PCMs cooling vest are of the cheapest, most mobile, and easiest equipment to wear.[6] PCMs as a medium for the storage of the latent heat energy are capable to change their phase in a certain temperature range during phase transitions between two states.[7] One of the well-known PCMs is paraffin. Paraffin is a family of hydrocarbons with the general formula of $C_nH_{2n} + _2$.[8] Paraffin materials have high boiling points and appropriate stability (up to 250°C). They are chemically stable, without phase segregation, with minimum sub-cooling during repetitive phase change, nontoxic, not corrosive, with low vapor pressure, odorless, and easily available.[7,9-11] Furthermore, paraffin materials have disadvantages such as low thermal conductivity and low thermal storage density.[8-12] Pure paraffin materials are expensive but their commercial compound, which are consist of different hydrocarbons, are cheap in compared to pure paraffin materials. On the other hand, the mixture of the materials can provide operational PCMs to possess a different thermal freezing-melting range and close to skin temperature.[13,14] Therefore, this study aimed to design the individual cooling vest using the cheap commercial paraffin compounds and then evaluation its effect on the heat strain parameters during physical effort under a hot condition in the climatic chamber.

## METHODS

This study included three stages: Preparing the paraffin compound with a proper melting point, designing the cooling vest, and evaluation the cooling effect of the cooling vest.

### Preparing the paraffin compound with proper melting point

For the appropriate performance of the PCMs, they should have a melting point lower than skin temperature and close to the skin temperature (15–35°C) to absorb sufficiently the heat and do not cause the skin irritation due to high coldness.[15] In this stage, it was prepared a composition of paraffin with a proper melting point in the range of 15–35°C from the cheap commercial paraffin compounds with a different melting point. It was used differential scanning calorimeter (DSC) technique to measure the accurate thermal properties of the paraffin such as melting point and latent heat. To analyze, it was used DSC 200 F3 Maia and aluminum pans. The analysis was performed with the constant increase in the temperature (10°C/min) at the thermal range −20–90°C and under a nitrogen gas flow of 50 ml/min, according to the method of ASTM D314-12. For calibrating the set, it was used indium before the test.[8]

### Designing the cooling vest

At first, it was prepared packs of paraffin. Because of the low thermal conductivity of paraffin, the packs were made of aluminum with a thickness of 0.125 mm and a thermal conductivity 237 W/(m °K). The aluminum pack was filled by 135 g of paraffin. Then the packs were sealed by heat machine. The number of the packs in each cooling vest was 17 packs. Each pack weighed 140 g and the total weight of cooling vest was 2.5 kg. Since the fabric of the cooling vest was polyester in the number of studies to make the cooling vest,[16-18] the cooling vest in our study was made of the polyester fabric and designed with an adjustable pattern based on the size of different individuals. It was considered 17 pockets (8 pockets on the front and 9 pockets on the back of the torso) in the inside layer of the cooling vest for fitting the cooling packs. Figure 1 shows the designed cooling vest and its pack.

### Evaluation the cooling effect of the cooling vest

For evaluating the effectiveness of cooling vest, an experimental study was carried out on ten healthy male students of the medical university of Isfahan, in 2015, in the climatic chamber of health school. The sampling method used in this study was nonprobabilistic sampling method. Inclusion criteria included no history of cardiovascular, respiratory, neuromuscular, and musculoskeletal diseases, epilepsy, seizure, diabetes, nonconsumption of high blood pressure drugs and medications affecting the heart rate, nonconsumption of coffee, caffeine, and alcohol from 12 h before the test. Exclusion criteria included the increased heart rate over 180 beats/min, oral temperature over 38.5°C and fatigue.[19] Candidates were examined by a physician for inclusion criteria and then the participants were selected. Also, they were asked to fill out the consent form developed by the medical ethics committee of the medical university of Isfahan. Also, they were talked about exclusion criteria and how to fill out the questionnaire and the test stages were clearly explained for them. It was gathered the participants' demographic information such as age. To assimilate the conditions of the cooling vests usage, all of the participants were asked to wear similar types of work clothes (30% polyester,

Figure 1: The designed paraffin cooling vest and the pack of it

70% cotton). To charge cooling packs, the refrigerator was used. The study was conducted on the participants under hot and dry conditions (air temperature [Ta] of 40°C, relative humidity [RH] of 40%) in the climatic chamber. Each participant was tested 4 times. They were tested in the following stages: Without cooling vest with light activities, with paraffin cooling vest with light activities, without cooling vest with moderate activities, with paraffin cooling vest with moderate activities. The light activity was done on a treadmill (Kettler model) with the speed of 2.8 km/h and the slope of 0%, and the moderate activity was performed on the same treadmill with the speed of 4.8 km/h and the slope of 0%.[20] In each stage of performing the test, at first, the participants rested and relaxed for 30 min, and their oral temperature and heart rate were measured. After that, the participants worked out on a treadmill for 30 min.[21] To evaluate the heat strain, the heart rate, oral temperature, and skin temperature were measured. During the test, the heart rate was measured every 2 min (using a sports polar tester) and the oral temperature (using oral thermometer of Beurer with accuracy of 0.1°C) and the skin temperature (using a device for measuring the skin temperature model Sina RT-923 with accuracy of 0.01°C) were measured every 4 min. For measuring the amount of sweating, the participants' weight was measured before and after each stage of the activity (using a digital scale of Hamilton model with an accuracy of 0.1 kg). The participants did not drink anything during the activities.[22] To calculate the percentage of the reduced sweating during activities with cooling vest, the following formula was used:

$$\% \text{ RSw} = 100\ [(\text{SwA} - \text{SwB})/\text{SwA}]$$

% RSw: percentage of the reduced sweating during activities with cooling vest.

SwA: Sweating rate during activities without wearing cooling vest.

SwB: sweating rate during activities wearing cooling vest.

Finally, data were analyzed using the statistical package for the social sciences (SPSS) 16. Kolmogrov–Smirnov was performed to check the normality of data distribution, and repeated measurement ANOVA test was used to determine the *P* value. The significance level was 0.05 for all tests.

## RESULTS

The results from paraffin thermal analysis by DSC technique showed that the latent heat of melting from the prepared composition of the paraffin was 108 kJ/kg. The range of phase change temperature was 24–34°C and the peak of the melting point was 30°C. The mean and standard deviation of the participant's age was 25.1 and 3.66, respectively. The values of the range, means, and standard deviation of the measured physical parameters are illustrated in Table 1. Furthermore, Kolmogrov–Smirnov test showed that the distribution of the data was normal ($P > 0.05$). Moreover, the result of the statistical analysis showed that there was not significantly difference between the dry temperature and the RH with cooling vest and without cooling vest in both light and moderate activities and the conditions were equal in both steps. The means and the standard deviation of the dry temperature for both activities were 40.04 and 0.38, respectively. The means and the standard deviation of the RH for both activities were 40.74 and 0.45, respectively.

The mean values of the measured heart rate during 2nd to 30th min every 2 min with cooling vest and without cooling vest in two physical activity levels are presented in Figure 2. The results showed that the difference for the mean values of the heart rate with cooling vest and without cooling vest during light activity ($P < 0.001$) and moderate activity ($P < 0.001$) were statistically significant. Furthermore, statistical analysis showed that the difference in the mean values of the variations of the heart rate in the activity time than the rest time with cooling vest and without cooling vest during both activities was statistically significant ($P < 0.05$).

The mean values of the measured oral temperature during 2nd to 30th min every 4 min with cooling vest and without cooling vest in two physical activity levels are shown in Figure 3. There was a significant difference for the mean values of the oral temperature with cooling vest and without cooling vest during light activity ($P = 0.049$) and moderate activity ($P < 0.001$). Furthermore, the results showed that the difference in the mean values of the variations of the oral temperature in the activity time than the rest time with cooling vest and without cooling vest during both activities was statistically significant ($P < 0.05$).

The mean values of the measured skin temperature during 2th to 30th min every 4 min with cooling vest and without cooling vest in two physical activity levels are shown in Figure 4. The results showed that the different for mean values of heart rate with cooling vest and without cooling vest during light activity ($P < 0.001$) and moderate activity ($P < 0.001$) were statistically significant. Furthermore, the results showed that the difference in the mean values of the variations of the skin temperature in the activity time than the rest time with cooling vest and without cooling vest during both activities was statistically significant ($P < 0.05$).

There was a significant difference for the mean values of sweating rate with cooling vest and without cooling vest during light activity ($P = 0.01$) and moderate activity ($P = 0.018$). The percentage of the reduced sweating rate was 31% and 33% during light activity and moderate activity with cooling vest, respectively.

**Table 1: Values of range, means and standard deviation of the measured physical parameters in light and moderate activities**

| Parameters | Light activity | | Moderate activity | |
|---|---|---|---|---|
| | Range | Mean (±SD) | Range | Mean (±SD) |
| Rest heart rate (beat/min) | 65-94 | 81.5 (10.20) | 67-96 | 81.71 (8.34) |
| Working heart rate with cooling vest (beat/min) | 84-124 | 103.9 (12.12) | 95-140 | 109.5 (12.57) |
| Working heart rate without cooling vest (beat/min) | 90-133 | 109.5 (13.80) | 102-152 | 117.71 (14.76) |
| Rest oral temperature (°C) | 36.1-36.9 | 36.49 (0.30) | 36.2-36.8 | 36.48 (0.19) |
| Working oral temperature with cooling vest (°C) | 36.3-37.2 | 36.77 (0.32) | 36.5-37.2 | 36.79 (0.20) |
| Working oral temperature without cooling vest (°C) | 36.5-37.2 | 36.87 (0.28) | 36.7-37.4 | 36.96 (0.22) |
| Rest skin temperature (°C) | 34.61-35.47 | 35.07 (0.26) | 34.69-35.37 | 35.04 (0.22) |
| Working skin temperature with cooling vest (°C) | 27.51-33.84 | 31.01 (1.96) | 26.50-32.82 | 29.69 (2.23) |
| Working skin temperature without cooling vest (°C) | 33.44-36.57 | 35.60 (0.98) | 33.35-37.17 | 35.64 (1.37) |
| Sweating rate with cooling vest (kg) | 0.1-0.3 | 0.18 (0.06) | 0.1-0.3 | 0.24 (0.07) |
| Sweating rate without cooling vest (kg) | 0.1-0.3 | 0.26 (0.07) | 0.2-0.7 | 0.36 (0.15) |

SD=Standard deviation

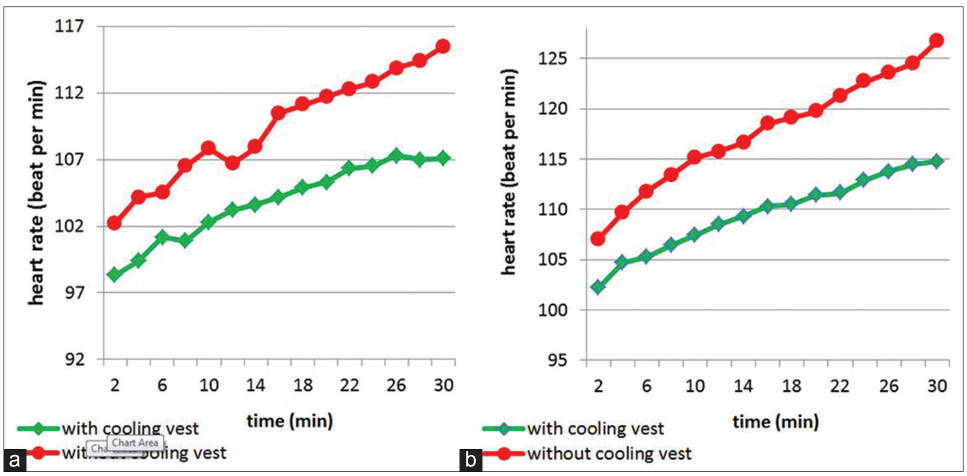


**Figure 2: The mean values of the participants' heart rate in 2nd to 30th min 1 time for every 2 min with and without a cooling vest: (a) with light physical activity (b) with moderate**

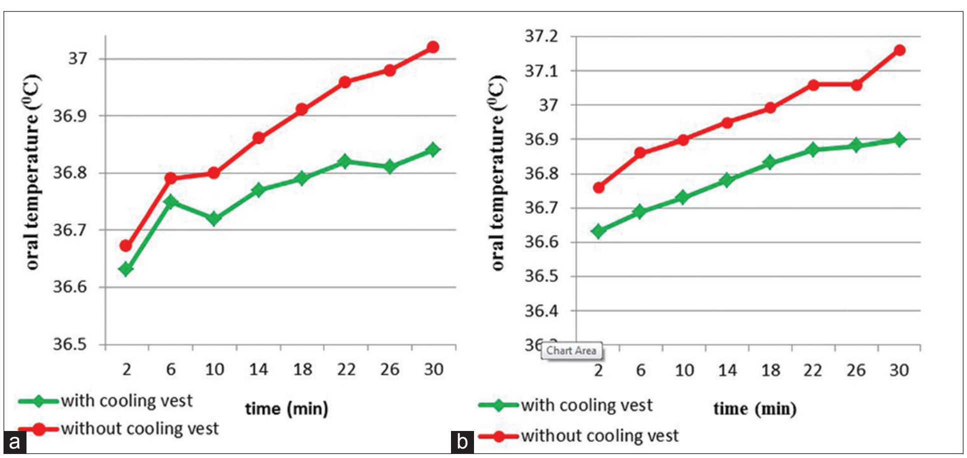


**Figure 3: The mean values of the participants' oral temperature in 2nd to 30th min 1 time for every 4 min with and without a cooling vest: (a) with light physical activity (b) with moderate physical activity**

## DISCUSSION

The results showed that the difference between the mean values of heart rate, oral temperature, skin temperature, and sweat rate of the participants with and without cooling vest in this study have been affected by the cooling vests and the difference has not relationship with the climatic conditions. In fact, this cooling vest

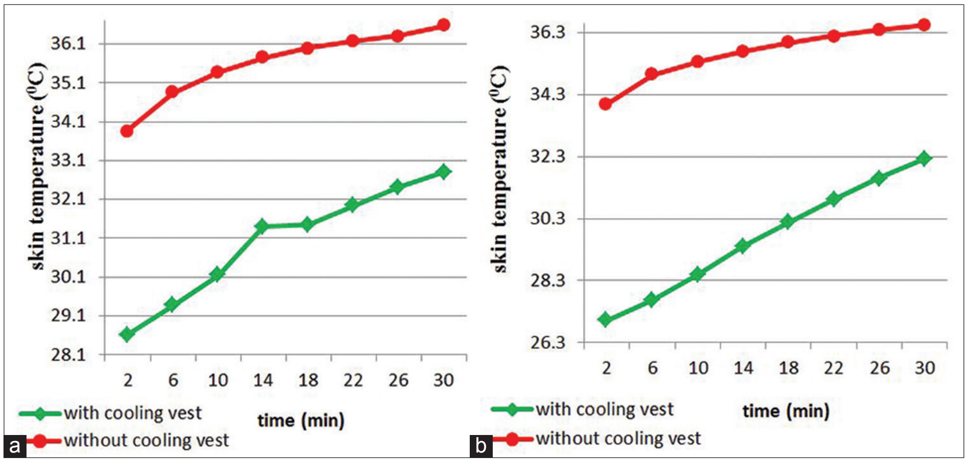


**Figure 4: The mean values of the participants' skin temperature in 2nd to 30th min 1 time for every 4 min with and without a cooling vest: (a) with light physical activity (b) with moderate physical activity**

creates a cooling micro climate to absorb the metabolic heat and prevent from the thermal exchange between the user and the external environment.[23] In exposure to hot condition, core-skin temperature gradient decreases and it causes an increase in diameter of the blood vessels near to the skin and increases blood flow and heat dissipation.[24] The designed cooling vest absorbs the transferred heat by blood vessels near to the skin through conduction and convection mechanism and decreases the skin temperature.[16] Then. the body core-skin temperature gradient increases due to the cooling effect of cooling vest. In fact, this temperature gradient between the skin temperature and the core temperature of the body can significantly increase the heat transfer and thereby reduce the core temperature of the body and consequently the oral temperature.[24] Because the melting point of the prepared paraffin compound was sufficiently lower than skin temperature, the significant heat transfer occurred.[25,26] Gao *et al*. recommend that the temperature gradient between the cooling vest and the skin surface be more than 6°C under hot conditions.[25] The results of this study showed that the temperature gradient of the designed cooling vest is >6°C. Moreover, some of the studies show that there is a good correlation between body temperature and the heart rate. Therefore, the decreased core temperature can reduce the heart rate.[27] These assumptions are supported by our results to indicate the skin temperature of the torso, the oral temperature, and the heart rate have significantly reduced in light and moderate activities with cooling vest than activities without cooling vest. Furthermore, the diagrams in the results section show that the skin temperature, oral temperature, and heart rate increase with lower speed during the light and moderate activities with cooling vest than activities without cooling vest, and it could be due to the above reasons. On the other hand, the results showed that the reduced sweating rate was 42% and 52% during light activity and moderate activity with the cooling vest, respectively which can prevent dehydration during activity. The dehydration can cause fluid and electrolyte imbalance in the body and lead to the heat-related illnesses.[28]

In general, the results showed that the cooling vest can reduce the heat strain by controlling the above parameters. Since torso has the highest capacity for the dissipation of the heat in compared to the other areas of the body.[29] There are several studies that show the effectiveness of the paraffin cooling vest on heat strain. In the study of Jovanovic *et al*., in 2013, was used the pure paraffin (n-hexane) with the range of phase change temperature of 13.8–21.2°C, the peak of the melting point of 18°C and the latent heat of melting of 237 kJ/kg. The said study conducted on 10 male trained soldiers under the temperature of 40°C on treadmill with speed 5.5 km/h. The results showed that the cooling vest was able to reduce the physiological strain through reducing the skin and rectal temperatures.[30] Of course, the pure paraffin is expensive and has not commercial and industrial usage. While the designed paraffin cooling vest was manufactured from the cheap commercial material. The results of this study showed that the latent heat of the prepared paraffin compound was 108 kJ/kg. This latent heat is lower than the latent heat pure paraffin (n-hexane) in the study of Jovanovic *et al*., this low latent heat of designed cooling vest limit the duration time of usage. However, the higher range of phase change temperature and the higher peak of the melting point in designed cooling vest than n-hexane increase the duration time of cooling effect and reduce irritation by chill.

Also, Chou *et al*. examined the performance of the pure paraffin cooling vest on eight students under the firefighting cloth in Ta of 30°C and RH of 50%. the result showed that the pure paraffin cooling vest with melting temperature of 28°C was effective in reducing the rate of heat storage in subjects.[31] In other study, Bendkowska *et al*. examined the cooling effects of the pure paraffin cooling vests (hexadecane with melting temperature at 18°C and octadecane with melting temperature at 28°C) on a thermal manikin in Ta of 20°C and RH of 50%. The results showed that both the cooling vests can control heat stain.[16] The results of the present study were agreement with the results of the above studies, but the latent heat of the designed cooling vest was lower than pure paraffin cooling vest in other studies.

Moreover, the results showed that the skin temperature was close to the natural skin temperature when the participant used cooling vest. Hence the cooling packs do not cause the skin irritation due to extreme coldness. Because this prepared paraffin compound has a high melting point, the low energy is needful for recharging the prepared paraffin compound and the paraffin packs only require a refrigerator to recharge.[26] In general, a disadvantage for the prepared commercial paraffin compound was the low latent heat in compared to the pure paraffin materials. Of course, the price of the commercial paraffin is very lower than the pure paraffin. The low latent heat reduces the duration of the cooling effect but, on the other hand, the duration of the recharging decreases.[25]

## CONCLUSIONS

The pure paraffin is expensive and has not commercial and industrial usage. Because of this, the cheap commercial paraffin compound was used in this study. However, the results showed that the use of cooling vest containing the commercial paraffin compound can reduce the heat strain through reducing heart rate, oral temperature, skin temperature, and sweating rate. This cooling vest with the proper melting point close to the skin temperature does not irritate the skin due to coldness. Hence, this type of cooling vest with low cost can be used to prevent heat strain and to increase the physiological stability against the heat. However, the disadvantage of the commercial paraffin compound was the low latent heat in compared to the pure paraffin materials. Hence, a matter with high latent heat such as ice must be used on side the commercial paraffin compounds in the packs of cooling vest for increasing latent heat.

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### Conflicts of interest
There are no conflicts of interest.

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## REFERENCES

1. Bernard TE, Cross RR. Heat stress management: Case study in an aluminum smelter. Int J Ind Ergon 1999;23:609-20.
2. Kjellstrom T, Lemke B. Loss of Worker Productivity Due to Projected Climate Change. IOP Conference Series: Earth and Environmental Science. IOP Publishing; 2009.
3. Golbabaei F, Omidvari M. Man and Thermal Environment. 3rd ed. Tehran: Tehran University Press; 2008. p. 99-107.
4. Nishihara N, Tanabe S, Hayama H, Komatsu M. A cooling vest for working comfortably in a moderately hot environment. J Physiol Anthropol Appl Human Sci 2002;21:75-82.
5. Teal W. Microclimate Cooling, Chemical Biological Individual Protection Conference. Natick, Mass, USA: US Army Natick Solder Center; 2006.
6. Kenny GP, Schissler AR, Stapleton J, Piamonte M, Binder K, Lynn A, *et al.* Ice cooling vest on tolerance for exercise under uncompensable heat stress. J Occup Environ Hyg 2011;8:484-91.
7. Zalba B, Marín JM, Cabeza LF, Mehling H. Review on thermal energy storage with phase change: Materials, heat transfer analysis and applications. Appl Therm Eng 2003;23:251-83.
8. Ukrainczyk N, Kurajica S, Šipušić J. Thermophysical comparison of five commercial paraffin waxes as latent heat storage materials. Chem Biochem Eng J 2010;24:129-37.
9. Sharma SD, Sagara K. Latent heat storage materials and systems: A review. Int J Green Energy 2005;2:1-56.
10. Himran S, Suwono A, Mansoori GA. Characterization of alkanes and paraffin waxes for application as phase change energy storage medium. Energy Sources 1994;16:117-28.
11. Holmer I, Kuklane K, editors. Improved Thermal Comfort with a Personal Cooling Vest. Proceedings of the 11th International Conference, Indoor Air 2008, Copenhagen, Denmark, 17-12 August 2008; 2008.
12. White JF. Flammability Characterization of Fat and Oil Derived Phase Change Materials. University of Missouri-Columbia; 2005.
13. Pasupathy A, Velraj R, Seeniraj R. Phase change material-based building architecture for thermal management in residential and commercial establishments. Renewable Sustain Energy Rev 2008;12:39-64.
14. Sharma A, Tyagi V, Chen C, Buddhi D. Review on thermal energy storage with phase change materials and applications. Renewable Sustain Energy Rev 2009;13:318-45.
15. Mondal S. Phase change materials for smart textiles – An overview. Appl Therm Eng 2008;28:1536-50.
16. Bendkowska W, Kłonowska M, Kopias K, Bogdan A. Thermal manikin evaluation of PCM cooling vests. Fibre Text East Eur 2010;18:78.
17. Sari A, Kaygusuz K. Thermal energy storage characteristics of myristic and stearic acids eutectic mixture for low temperature heating applications. Chin J Chem Eng 2006;14:270-5.
18. Gao C, Kuklane K, Holmér I. Cooling Effect of a PCM Vest on a Thermal Manikin and on Humans Exposed to Heat. 12th International Conference on Environmental Ergonomics, Biomed doo, Ljubljana, Slovenia; 2007.
19. Dehghan H, Parvari R, Habibi E, Maracy MR. Effect of fabric stuff of work clothing on the physiological strain index at hot conditions in the climatic chamber. Int J Environ Health Eng 2014;3:14.
20. ISO I. 8996. Ergonomics – Determination of Metabolic Heat Production. Geneva, Switzerland: International Organization for Standardization; 1990.
21. Bennett BL, Hagan RD, Huey KA, Minson C, Cain D. Comparison of two cool vests on heat-strain reduction while wearing a firefighting ensemble. Eur J Appl Physiol Occup Physiol 1995;70:322-8.
22. Moran D, Pandolf K, Shapiro Y, Laor A, Heled Y, Gonzalez R. Evaluation of the environmental stress index for physiological variables. J Therm Biol 2003;28:43-9.
23. Kayacan Ö, Kurbak A. Effect of garment design on liquid cooling garments. Text Res J 2010;80:1442-55.
24. Sarkar S, Kothari V. Cooling garments – A review. Indian J Fibre Text Res 2014;39:450-8.
25. Gao C, Kuklane K, Holmer I. Cooling vests with phase change material packs:

The effects of temperature gradient, mass and covering area. Ergonomics 2010;53:716-23.
26. Laprise B, Teal W, Zuckerman L, Cardinal J. Evaluation of Commercial Off the Shelf and Government Off the Shelf Microclimate Cooling Systems. DTIC Document; 2005.
27. Griffin JC, Jutzy KR, Claude JP, Knutti JW. Central body temperature as a guide to optimal heart rate. Pacing Clin Electrophysiol 1983;6(2 Pt 2):498-501.
28. Sawka MN, Montain SJ. Fluid and electrolyte supplementation for exercise heat stress. Am J Clin Nutr 2000;72:564-72.
29. Jovanovic D, Karkalic R, Zeba S, Pavlovic M, Radakovic SS. Physiological tolerance to uncompensated heat stress in soldiers: Effects of various types of body cooling systems. Vojnosanit Pregl 2014;71:259-64.
30. Jovanovic DB, Karkalić RM, Tomić LD, Veličković ZS, Radaković SS. Efficacy of a novel phase change material for microclimate body cooling. Therm Sci 2014;18:657-65.
31. Chou C, Tochihara Y, Kim T. Physiological and subjective responses to cooling devices on firefighting protective clothing. Eur J Appl Physiol 2008;104:369-74.