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ORIGINAL ARTICLE

Evaluating the Performance of American PCM and Iranian Spadana Gel Ice Cooling Vest on the Perceptual and Physiological Strain Score Indexs of Asaluyeh in Iran

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ABSTRACT
The aim of this study was to compare the effect of change phase paraffin cooling vest and Iranian Spadana Cooling Vest on the perceptual strain score index (PeSI),physiological strain score index (PSI)of Asaluyeh in Iran. This cross-sectional interventional study was conducted in 2016 on 90 workers with an identical level of physical activity and uniforms in Asaluyeh, southern Iran .The questionnaires of PeSI, heat strain score index (HSSI)and PSI were also administered to assess the PeSI and the sweating while wearing the vests and in the control group. The WBGT index was measured for 120 min as well, and the checklist of individual strength (CIS) and the comfort assessment questionnaire were filled by the workers too. The repeated measures Test and the statistical analysis software SPSS 21 were used to analyze and compare the data. The WBGT mean index was 37.65°C for all the three groups. The mean scores of PeSI, HSSI, PSI, and CIS in the groups with paraffin change phase cooling vests and Iranian cooling vests had a statistically significant difference compared to the control group (P<0/001). Wearing the paraffin cooling vests and the Iranian cooling vests for 90 min can reduce acceptably and appropriately, the heat stress level of the users by decreasing the oral temperature, the heart rate, and the PeSI value while increasing the CIS score.

KEYWORDS: *Spadana cooling vest, Phase change paraffin vest, Physiological strain score index (PSI), Perception strain score index (PeSI)*

INTRODUCTION
Heat is one of the harmful physical factors of the working environment, which can affect the individuals in the workplace. It can negatively affect the health of the workers, causing cardiovascular diseases and workplace accidents. Increased body temperature and the lack of thermal comfort induce anger, increases irritability and restlessness in individuals, and makes workers inattentive to the safety instructions and safe working[1-2]. Therefore, heat strains may lead to physiological reactions including increased skin temperature, sweat, increased heart rate, and increased deep temperature, as well as diseases caused by exposure to heat including mild and moderate disorders and thermal shocks. In mild and moderate disorders such as muscle cramps and fatigue due to heat, temperature regulation of the human body is not affected, but in thermal shocks, the temperature regulation of the human body is disrupted and this imperils the life[3]. The mutual

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effect of six fundamental factors determines the human heat environment and its thermal comfort feeling [4]. These parameters are categorized as behavioural and environmental factors. Atmospheric temperature, radiant temperature, humidity, and airflow are the four basic environmental variables. The degree of metabolism and dressing are behavioural factors that affect human response to hot environments. Therefore, each thermal stress consideration should regard these six factors [5] . The heat stress indices are used to assess heat stress. The wet bulb globe temperature (WBGT) index is one of the most-used experimental indices in the world [6] . Another one of the index, newly codified according to the perceptual-observational method, is the heat strain score index (HSSI) [7-8] .

There are several ways to manage heat stress, including engineering methods, administrative methods of management, and personal protection methods such as the use of cooling vests, which absorbs excess heat in warm environments [9,10] .Cooling vests are divided into two categories that include liquid cooling or air-cooled vests and phase change material vests [11] . Phase change materials (PCM) can absorb, store, or release a lot of energy in the form of latent heat in a narrow temperature range defined during the phase shift between the two modes of material [12]. Among the diverse phase change materials, the most well-known PCM is water, which turns into ice at 0°C, and has a latent heat storage capacity of 335 joules per gram. The advantages of the ice cooling vests include the high latent heat of melting, accessibility and inexpensiveness, innocuousness, and non-irritation to the skin. However, long-term exposure to ice may cause tissue damage, which has limited the use of ice cooling vests [13] . Another one of the well-known PCMs is paraffin [14]. The different kinds of paraffin have a high boiling point and high stability up to 250°C, that is, they are chemically stable and do not show any phase separation. Moreover, they are non-toxic, non-corrosive, odourless, harmless, and readily available [15]. In many workplaces, because of the climate and ambient heat, this method may not be applicable. In addition, these have technical and economic limitations.

Therefore, to reduce the level of heat stress for hot and humid conditions, the performance and the efficiency of Iranian Spadana cooling vest, and the American Techkewl-7026 phase change paraffin-cooling vest have been examined and assessed in Asaluyeh with weather conditions of high temperature and high relative humidity.

MATERIALS AND METHODS

Weather conditions of the workplace: The study was conducted on 90 workers of Mobin Petrochemical and Zagros in Asaluyeh, southern Iran. They were exposed to heat stress in open space in the summer of 2016, with an average temperature of 47.02°C (±1.95°C) and a relative humidity of 95.16% (±4.7%).

Table 1. Weather conditions of the workplace in this study

Parameters measured	Thevalue of Parameters in test			
	Mean	Standard deviation	Min.	Max.
Dry temperature(°C)	39.10	1.85	33.3	42.30
Wet temperature(°C)	39.20	1.74	34.3	41.25
Bulb Globe temperature(°C)	37.10	1.40	36.2	38.80
Relative humidity(%)	98.20	1.60	93.7	100.00
WBGT index(°C)	37.65	2.10	35.7	39.10

Subjects: This analytical-descriptive, cross-sectional, and interventional study was conducted on 90 individual (30 individuals with Iranian Spadana cooling vest, 30 individuals with change phase paraffin cooling vests, and 30 individuals as the control group) workers in Asaluyeh. The inclusion criteria were the absence of cardiovascular, infectious, and respiratory diseases, blood pressure, diabetes, musculoskeletal diseases, the individuals registered in the medical file as appropriate to assess the PSI, and nil to low consumption of caffeine and alcohol. The exclusion criteria were the lack of needed cooperation and/or fatigue due to any reason.

Three male with identical functions, similar work uniforms, with (body mass Index) BMI lower than 27, were assessed simultaneously for two hours. One wore the Iranian Spadana cooling vest, one wore the American change phase cooling vest, and the third, as part of the control sample, did not wear any such vests. The aim was to compare the impacts of the Spadanacooling vestand phase change-cooling vests on the PSI in the hot and humid conditions of Asaluyeh.

Features of the material used in change phase vests: The Iranian Spadana cooling vest made of 70% cotton and 30% polyester with 10 pockets for gel ice packs, total weight of 2.3kg, and the American change phase paraffin model Techkewl-7026 made of 100% cotton with four pockets for PCM packs, and the total weight of 2.2kg were used. PCM is naturally in liquid form, according to the catalog and manufacturer's instructions should be placed in temperature lower than 15 degrees centigrade for two hours to be used and recharged. After freezing the PCM packs, they are placed in the provided pockets in the cooling vests that can be used for two hours.

The experiment protocol: In order to perform the experiments, after determining the samples and 15 min of rest for the participants, both the PeSI and HSSI questionnaires were filled every 15 min to assess the PSI. Then, the CIS was given to the participants every 15 min along with the necessary explanations, to assess the ability to do things. The WBGT index was also calculated and measured every 30 min, in order to identify the type and the condition of the working environment.

The rate of decline of physiological strains of the heart rate was measured by Sports Tester (Polar) every 10 min and OT was measured every 10 min by a Breuer oral thermometer. The weight (weight loss being calculated and then added to the amount of water during the activity, and the sum divided by the time) was logged in the beginning and end of the test. Then, the workers with the cooling vests filled the vest comfort questionnaire every hour.

Equation 1 was used to calculate the PSI:

(Equation 1)

$$PSI = 5 \times (Tct - Tc0) / (39.5 - Tc0) + 5 \times (HRct - HRc0) / (180 - HRc0)$$

In equation 1, Tct shows the deep (oral) temperature of the body during activity; Tc0 shows the deep (oral) temperature of the body at resting; HRc shows the heart rate during the activity; HRc0 shows the heart rate at rest[16] . The final score of PSI is between zero and ten, where a score of zero to two reflects the absence of heat stress; a score of three to four reflects low heat stress; a score of five to six reflects moderate heat stress; a score of seven to eight reflects high heat stress, and a score of nine to ten reflects a severe heat stress.

The comfort assessment questionnaire had 10 questions and each question had five points; so, the maximum score of the questionnaire was 50. The maximum points were given for the most positive perspective (strongly disagree: 1, disagree: 2, normal: 3, agree: 4, strongly agree: 5).

The HSSI questionnaire had 17 items about the atmospheric conditions of the environment, where items from 1 to 12 were checked through questioning and items from 13 to 17 were checked through observing the individual and the score of each item (written in front of it in parenthesis) was checked, and multiplied by the impact coefficient rate (written inside parenthesis in front of each question) and the multiplication was recorded in the box in front of each question, and finally, the values inside the boxes were added together.

Table 2. The HSSI score value for assessment

***P*-value**	**Assessment**	
<13.5	Lacked heat stress	First level of heat strain risk or the green zone
13.6<and <18	More accurate assessment of the heat strain	Second level of heat strain risk or the yellow zone
18<	Appropriate control measurements were performed to reduce strain	Third level of heat strain risk or the red zone

The CIS questionnaire had 20 questions filled through questioning, and each question had six points (no and never: 0, yes and always: 6); hence, the maximum questionnaire score was 120, and in responding the questions, the maximum score from positive perspective was recorded .The way of calculating the PeSI, which is dependent on the two parameters of thermal sensation and perceptual activity intensity, is perceived as follows:

In Table 3&4), the way of scoring and evaluating the PeSI variables are expressed:

$$PeSI = 5 \times \{(TS - 1) / 4)\} + 5 \times (PE / 10)$$

A) TS: Thermal sensation:

Table 3. The TS value for assessment

Ts	**1**	**2**	**3**	**4**	**5**
Assessment	Comfortable	A little hot	Warm	Hot	Too hot

B) PE: Perceived exertion:

Table 4. The TS value for assessment

Pe	**0-1**	**2-3**	**4-5**	**6-7**	**8-9**	**10**
Assessment	Extremely easy	Easy	Slightly easy	A little hard	Hard	Very difficult

The final score of PeSI was between zero and ten, where a score of zero to two reflected the absence of heat stress; a score of three to four reflected low heat stress; a score of five to six reflected moderate heat stress; a score of seven to eight reflected high heat stress, and a score of nine to ten reflected a severe heat stress.

In order to analyse and compare the data in different times and groups, repeated measures test was used and in order to evaluate the comfort of the Iranian and the foreign cooling vests, the t-test was used. All the analyses were performed using SPSS 21(Chicago, IL, USA). The results were reported with a significance level of 5% with trust about 95%.

RESULTS

The mean BMI for the participants with Iranian cooling vests was 25.42±3.6, and with foreign cooling vests 25.15±2.5. The mean BMI for the control group was 25.58±2.47. The WBGT mean index was 37.65±2.1°C for the three groups .The mean of weight change of participants in the group with Iranian groups cooling vests during the test and within two hours perspiration measurement was 0.98±0.33gr per h, for the group with foreign cooling vests was 0.68±0.21 gr per h, and for the control group was 01.35± 0.35 gr per h.

Table 5 displays the mean and the standard deviation of the measured parameters in the three test groups; and the statistical analysis proved that the average HR, OT, PSI, and sweating has a significant difference between the groups with Iranian and foreign cooling vests compared to the control group (P<0.001).The mean score of the comfort questionnaire of the Iranian cooling vest comfort was not significantly different from that of the foreign one (P>0.05). However ,the mean PeSI and HSSI in participants with the Iranian and foreign cooling vests are significantly different compared to the control group (P<0001). Besides, the mean CIS score in the group with paraffin phase change cooling vests and Iranian Spadana cooling vest was significantly different compared to the control group (P<0.001). However ,the mean of BMI in the group with Iranian and foreign cooling vests was not significantly different with the control group (P>0.05).

The time of HR changes in the three test groups is shown in Fig. 1; where the mean HR in participants with Iranian and foreign cooling vests is lower than the mean HR in the control group (between 7bpm and 9bpm) which is statistically a significant difference (Table 5,P<0.001). However, the difference in the mean HR in participants with Iranian and foreign cooling vests was not significant (P>0.05).

The time of OT changes in the three test groups is shown in Fig. 2; where the mean OT in the participants with Iranian and foreign cooling vests is lower than the mean OT in the control group, which is statistically a significant difference (Table 5, P<0.001), but the difference in the mean OT in participants with Iranian and foreign cooling vests was not significant (P>0.05).

The time of PSI changes in the three test groups in Fig. 3 shows that the mean PSI in groups with Iranian and foreign cooling vests is lower than the mean PSI in the control group (between 3 and 3.5 points) which is statistically a significant difference (Table 5, P<0.001), but the difference in the mean PSI in participants with Iranian and foreign cooling vests was not significant (P>0.05).

The time of CIS index changes in the three test groups in Fig. 4 shows that the mean CIS index in participants with Iranian and foreign cooling vests is higher than the mean CIS index in the control group, which is statistically a significant difference (Table 5, P<0.001), but the difference in the mean CIS index in participants with Iranian and foreign cooling vests was not significant (P>0.05). However, a high correlation between the index values of CIS in the participants with the Iranian and the foreign cooling vests, and the control group over time was observed according to the number of regression (R^2, P=0.001).

The time of HSSI changes in the three test groups in Fig. 5 shows that the mean HSSI in participants with Iranian and foreign cooling vests (without heat stress) is lower than the mean HSSI in the control group (with moderate heat stress) which is statistically a significant difference (Table 2&5, P<0.001), but the difference in the mean HSSI in participants with Iranian and foreign cooling vests was not significant (P>0.05). However, the high correlation between the index values of HSSI in the participants with the Iranian and the foreign cooling vests, and the control group over time was observed according to the number of regression (R^2, P=0.001).

The time of PeSI changes in the three test groups in Fig. 6 shows that the mean PeSI in participants with Iranian and foreign cooling vests (with moderate heat stress) is lower than the mean HSSI in the control group (with high heat stress) which is statistically a significant difference (Table 5, P<0.001), but the difference in the mean PeSI in participants with Iranian and foreign cooling vests was not significant (P>0.05). Moreover, the high correlation between the index values of PeSI in the participants with the Iranian and the foreign cooling vests, and the control group over time was observed according to the number of regression (R^2, P=0.001).

Table5. Mean and standard deviation of the measured parameters in Iranian Spadana cooling vest, paraffin phase change cooling vests and without vests

Parameters measured	Group with Spadana cooling vest		Group with paraffin phase change cooling vests		Controls group		Significance level
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	
Heart rate (bpm)	91.76	5.60	89.53	4.90	97.07	9.28	<0.001
Oral temperature (°C)	36.70	0.39	36.63	0.37	36.78	0.42	<0.001
PSI score	3.18	0.94	2.29	0.69	6.12	1.30	<0.001
The comfort of vest score	38.40	1.45	39.16	1.24	-	-	<0.001
perspiration measurement (grams per hour)	0.98	0.33	0.68	0.21	01.35	0.35	<0.001
PeSI score	7.39	2.25	6.36	1.98	9.95	1.56	<0.001
HSSI score	6.33	0.95	5.92	1.22	13.28	3.50	<0.001
CIS score	75.04	5.69	84.38	6.23	55.33	3.14	<0.001

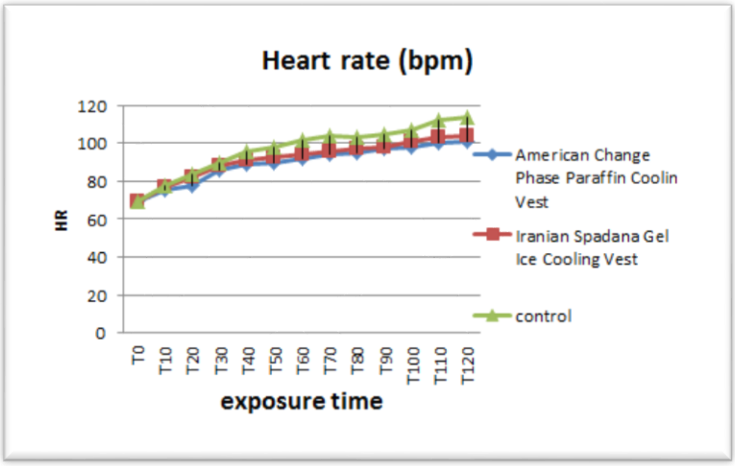

***Fig*.1.** Trend of HR changes during the test period among three study groups

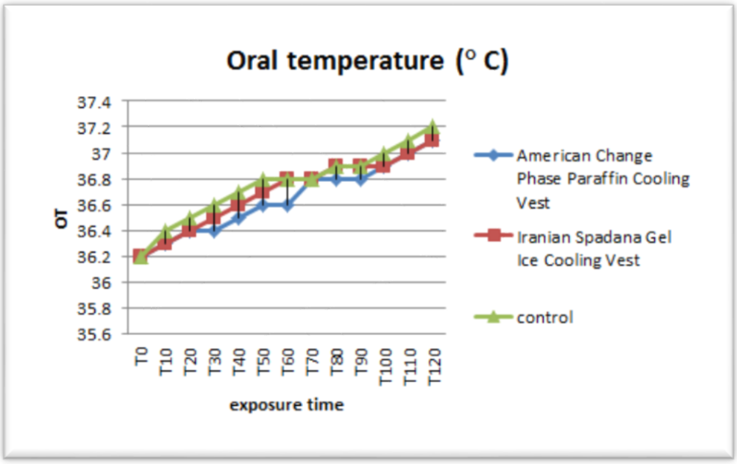

***Fig*.2.** Trend of OT changes during the test period among three study groups

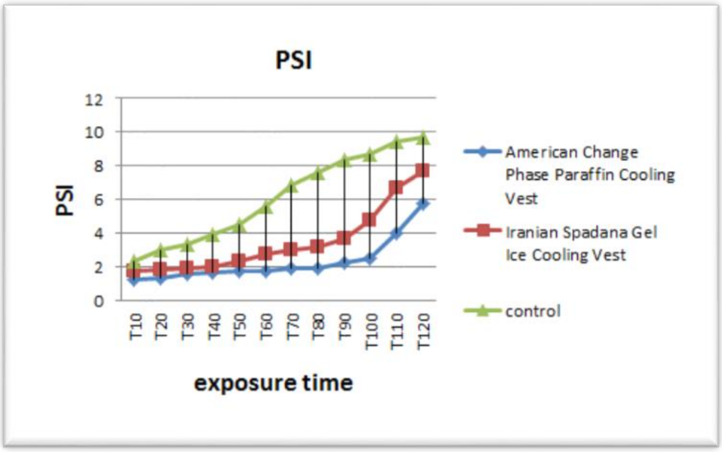

***Fig*.3.** Trend of PSI changes during the test period among three study groups

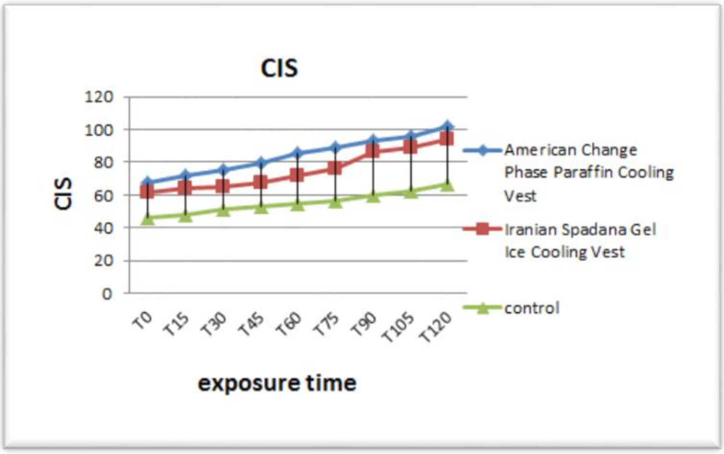

***Fig*.4.** Trend of CIS changes during the test period among three study groups

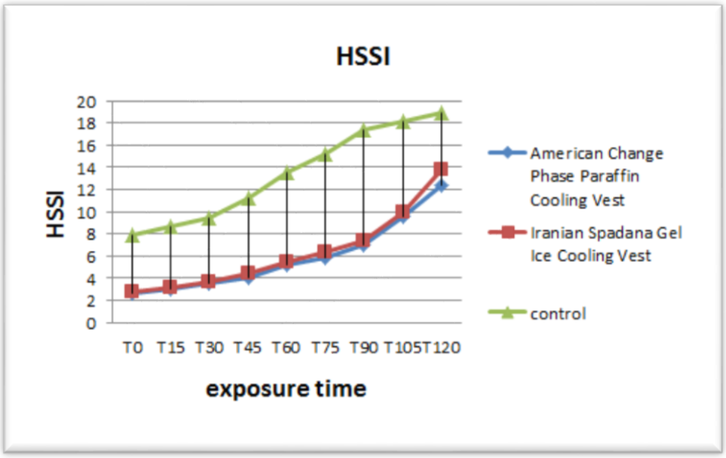

***Fig*.5.** Trend of HSSI changes during the test period among three study groups

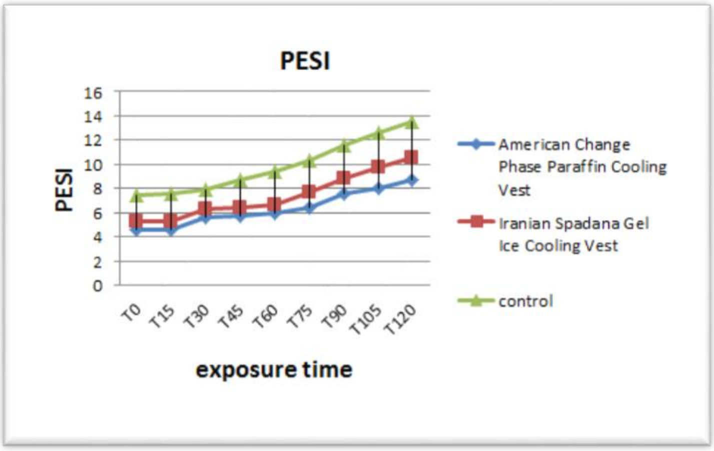

***Fig*.6.** Trend of PESI changes during the test period among three study groups

DISCUSSION

According to the results of the WBGT index, the heat stress due to the necessity of implementing the project (the permitted WBGT for continuous work and light, medium, and severe activities should be 30°C, 26.7°C, and 25°C, respectively). As represented in Table 1 and Fig. 1 to Fig. 6, the values of the mean HR, OT, and sweating PSI index, and the PeSI and HSSI values in the participants with Iranian and foreign cooling vests were lower compared to the control group (PSI index between 3 and 3.5). Hence, considering the similarity of the test conditions for the different groups studied, the Iranian Spadana cooling vest and the American paraffin phase change model Techkewl-7026 were effective in reducing the PSI in the hot warm and humid Asaluyeh summer. This is because body heat, taken to the surface skin by circulation of blood flow, is absorbed by the PCM packs, and this reduces body temperature and the PSI. Besides, the fact that PCM can absorb, store, and release a lot of energy in the form of latent heat during phase transition between solid and liquid is significant. Ourprevious study that aimed to investigate the cooling effect of Iranian vests containing phase change pack material in the hot and humid conditions of the Persian Gulf, interventions were performed on six sailors in the engine room of an oil tanker in the summer of 2013. The HSSI, OT, and blood pressure of the individuals, in both states of with and without the vests, were measured for two hours and the data were analyzed using the t-test..The mean temperature of OT in the 30th min of exposure to the heat without cooling vests was 36.98±0.22°C, and it was 36.68±0.2°C with cooling vests. In the 60th min of exposure to the heat, the mean OT in the state without cooling vests was 37.06±0.25°C, and 36.78±0.16°C in the state with cooling vests. In addition, the HSSI was 12.72±3.03 without cooling vests and 8.65±2.9 with cooling vests. Therefore, the Iranian cooling vests containing phase change material packs lead to decreased heat stress (OT and perceived heat) in the hot and humid climate of the Persian Gulf [17] .The performance of an ice cooling vest was examined on nine trained fire fighters walking on a treadmill at a speed of 5km per hour and 7.5% of gradient in conditions of 51°C and relative humidity of 14%. The use of ice cooling vests was effective in improving the cardiovascular conditions and regulating body heat in the fire fighters during the exercise [18] . Moreover, in another study aimed to examine the individual cooling effect of PCM on improving individuals' heat comfort in a simulated office with a temperature of 340°C,by examining eight male volunteers in an atmospheric conditioned room; where the temperature of the individuals' skin was reduced by 3.20°C and remained at 33.3°C. The cooling through PCM can be considered as an alternative for heat comfort for administrative employees [19] .The PCM vests (mainly made of sodium sulfate, with a melting point of 280°C) were effective on heat mannequins and on individuals [20] . Reviewing the opinions and views of the individual participants of the present study, about the degree of comfort of Iranian and foreign cooling vests, showed that the participants were satisfied with the performance of the vests, with wearing and taking them off, and were happy with the designs and models of the vests. Nevertheless, about the flexibility of the vests, the typical comments stated that due to the large and solid-state of the PCM packs, the mobility of the user will be reduced, which is consistent research that recognized reduced mobility as one of the disadvantages of the PCM vests [21].

CONCLUSION

Due to the similarity of the test conditions for the different groups studied, the American paraffin phase change cooling vest model Techkewl-7026 and the Iranian Spadana cooling vestcan be used in hot and humid conditions for 90 min. They are effective in reducing the PeSI and HSSI and improving productivity, the CIS, motivation, and the health of the employees, and they reduce adverse physiological responses. Due to the good level of user satisfaction towards the Iranian Spadana cooling vestand its similar and identical performance compared to the American paraffin phase change cooling vest model Techkewl-7026, the Iranian Spadana cooling vestcan be extensively used in hot and humid workplaces to reduce the heat stress.

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The authors declare that there is no conflict of interests.

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