Journal of Engineering Science and Technology
Vol. 16, No. 2 (2021) 1402 - 1415

WEARING A FIBROUS PROTEIN (CV-F) COOLING VEST TO REDUCE FATIGUE AMONG INDONESIAN *PENCAK SILAT* ATHLETES: IS IT EFFECTIVE?

JOHANSYAH LUBIS[1,*], ABDUL SUKUR[1], EKO JULI FITRIANTO[1], DEWI SULIYANTHINI[1], ASTRI AYU IRAWAN[2], AGUNG ROBIANTO[1], ARIDHOTUL HAQIYAH[3], NADYA DWI OKTAFIRANDA[1]

[1]Universitas Negeri Jakarta Jl. Rawamangun Muka Raya, Jakarta 13220, Indonesia
[2]Universitas Singaperbangsa Karawang Jl. HS. Ronggo Waluyo, Karawang 41361, Indonesia
[3]Universitas Islam 45 Jl. Cut Mutia Raya No. 83, Bekasi 17113, Indonesia
*Corresponding Author: johansyah.sport@unj.ac.id

Abstract

Efforts to reduce or at least minimize fatigue among martial arts athletes, including *Pencak Silat*, have been made; one of which is by wearing a cooling vest. This paper aimed to identify the effectiveness of recovery using composition of fibrous protein (Cv-f) cooling vest among Indonesian *Pencak Silat* athletes. As many as 27 athletes were required to join in an experiment where they had to perform a 1600m running with such predetermined aspects as the level of humidity, temperature, and other conditions on an athletic track. The participants were divided into three groups to see the difference between the group receiving the treatment (wearing the cooling vest) and one which did not receive any treatment. The results showed that the vest gave comfort either in terms of cooling process or in terms of physiological responses due to the vest wearing. This implied that the vest gave significant contribution of fatigue reduction both for long and peak exercises.

Keywords: Athletes recovery, Fibrous protein (Cv-f) cooling vest, *Pencak Silat*.

1. Introduction

Fatigue due to sports activities, particularly martial arts, is both a physiological and psychological phenomenon causing degradation of athletes' functional skills leading to physical injury [1]. Fatigue is commonly caused by either training or matching activities leading to muscular damage, inflammation changes, and pain during physical activities [2]. To this relation, recovery needs to be optimized in order to reduce fatigue and increase performance capability to reach quick recovery [3], as the recovery is individual responsibility [4]. Heart Rate Recovery (HRR) measurement is one of the ways to optimize training [5]. Furthermore, recovery processes can be carried out through a variety of strategies; one of which is by wearing a cooling vest aiming to reduce heat during sports activities [6].

There have been several studies researching on recovery process for athletes Pooley et al. [7], who investigated recovery strategies through various strategies, found that Active Recovery (AR) and Cold-Water Immersion (CWI) were more significant recovery interventions in comparison with Static Stretching (SS) among footballers. It was also proven that cooling vest could effectively help athletes' recovery as Zare et al. [8] the use of optimized cooling vest was as effective as that of commercial paraffin cooling vest to control thermal stretching. During warming-ups, cooling vest was effective to enhance Tb, HR, and thermal discomfort perception, and to increase the performance of 5-km running in a simulation conducted in hot and humid weather of man and woman competitive runners [9]. In the meantime, Mneimneh et al. [10] investigated the development of cooling vests effective for paraplegia (PA) aiming to develop bioheat PA models changed and combined with cooling vest models to study the performance of the cooling vest during training. Raad et al. [11] also developed a cooling vest based on Maisotsenko cycle evaporative cooling technique (M-cycle) in which the air was cooled evaporatively. The cycle-M cooling vest succeeded in decreasing back temperature [11]. A new combination of PCM and solid desiccant layer was developed by Itani et al. [12] in which the fabric-PCM-desiccant model was able to predict water temperature and content of microclimate air layer due to the presence of PCM-desiccant.

There have also been other cooling vests commercially found in the market; one of which was the cooling vest by Kenny et al. [13] featuring insulated vests (NBC suit) using such fabrics as polymers, polyesters, etc. However, there is very limited number of studies investigating fibrous protein cooling vests made of wools. Therefore, it is necessary to create such a cooling vest which is effective and affordable to help athletes' recovery process. This study aimed to identify the effectiveness of fibrous protein (Cv-f) – based cooling vests for martial arts athletes' activities.

2. Literature Review

2.1. Recovery

Exercising with high or low intensity with the same amount of work will cause the same fatigue [14], as training and competition fatigue will cause decreased muscle performance due to peripheral fatigue and central fatigue caused by reduced motor drive of the CNS [15]. Athletes need to be returned to the condition prior to their fatigue [16]. The recovery period is important, because accumulated fatigue not only reduces performance but also increases the risk of injury, cognitive and mood disorders (irritability, difficulty concentrating, lack of sleep) which causes overtraining [17]. Recovery strategies include alternating soaking in contrasting water, with a combination of sports massage and cold-water immersion (15^0C), active recovery, compression, massage, contrast water therapy, cryotherapy, and combined recovery interventions [18]. One of the effects of cryotherapy is on muscle function and flexibility [19]. Conventional cryotherapy with prolonged application of ice will cause direct damage to muscle strength and activity, proper Cold Water Immersion (CWI) after exercise for no more than 10 minutes on pure hypoalgesia has a greater benefit on recovery [20]. Evaluating on recovery which is widely used is using Heart Rate Recovery (HRR), from the end of exercise to a specific recovery moment [5, 21]. CWI is a popular recovery intervention after exercise. CWI induces significant physiological and biochemical changes in the body [22]. Recovery is often necessary to minimize fatigue and maximize recovery between competitions and therefore should be prioritized [23].

2.2. Fibrous protein cooling vest (Cv-f)

Cooling vest is one of the methods of cryotherapy in which many studies confirm to be able to reduce thermal and cardiovascular pressure by reducing body temperature when body temperature rises during activity [24]. The cold temperature in the cooling vest uses commercial paraffin or ice, which is equally effective in controlling thermal strain [8]. Cooling vest for endurance while running 95% VO2max can be increased by 49 seconds; the perception of thermal condition and skin moisture shows changes in higher levels of satisfaction [25]. Cooling vest modification made from fibrous protein as the first ingredient in the skin of the human body has a good level of comfort for athletes [26]. Comfort in clothes is important in terms of thermal and moisture behaviors. Modification of the fiber surface brings new functions and properties to fibrous materials, but comfort can change due to thermal and humidity [27], wool in the 1950s was the main choice for football, rugby, cricket, cycling, sailing and sports, and outdoor activities, but over time has sunk since the emergence of synthetic fibers in mass production using eroded wool [28]. The application of supercritical CO_2 ($scCO_2$) technology in sheep wool processing will be cleaner and avoid the formation of toxic waste, where $scCO_2$ is for sterilization, lanolin extraction, and cleaning and drying [29]. The basic layer of Merino wool is claimed to be able to regulate body temperature in all conditions, protect it when it is cold, but stay cool when it is hot so that the skin remains dry and becomes calm [30]. We can see the composition of wool and polyester in the market based on the percentage of each of these fibers [31].

This wool fibrous protein cooling vest is designed to make it easy to wear for human body as well as to replace the ice pack (see Fig. 1).

Fig. 1. Fibrous protein cooling vest.

3. Materials and Methods

3.1. Participants

Participants in the study were 27 male *Pencak Silat* student athletes selected through purposive sampling. Overall age mean was 20.15 (± 0.91) years old, and baseline weight was 66.851 (1.065±) kg. Prior to the experiment, the participants were given an explanation of the research implementation protocol and data collection. Participants had stated their agreement through the informed consent sheet provided.

Participants were asked not to do rigorous activities for the previous 2 days, and not to eat heavy meals 4 hours before the study. They were also asked not to 1 day before and not to drink coffee 12 hours before. Participants who did not comply with these instructions were considered to be in the experimental exclusion criteria. Experiments were carried out on the same day using a 100% (CV-f100), 80% (CV-f80%) and 50% (CV-f50) fibrous protein cooling vest. When running 1600 meters, the participants wore sportswear and sports shoes while running on a standard athletic track.

3.2. Preliminary procedure

Before the experiment was carried out, the wool protein fiber was analysed for analysis of its fiber composition at the Bandung Textile Center (BBT) with the Bundesman test method to measure the composition percentage of wool fiber in Moisture Content (MC) and Moisture Regain (MR) to determine the percentage of water absorption capacity as presented in Fig. 2.

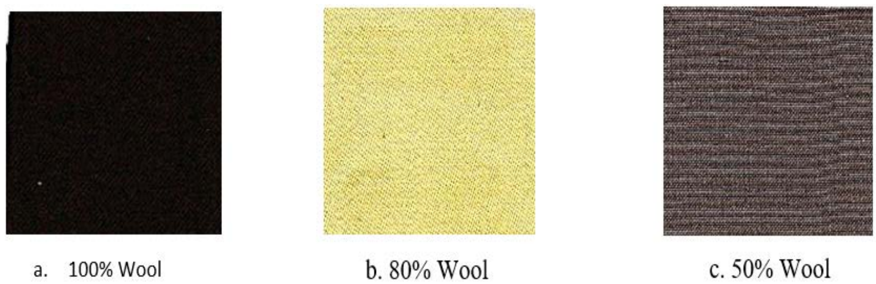

Fig. 2. Protein fiber 100% (a), 80% (b), 50% (c).

CV-f100 wool fiber; (MR 11.26. MC 10.14). CV-f80 wool fiber; (MR 7.84. MC 8.51); CV-f50 wool fiber; (MR 2.93. MC 3.02. CV-f100); and MC when not in use has an absorption capacity of 10.14% and when used it can absorb a maximum of up to 11.26% (maximum 12%). An examination of the health condition was then carried out and there were no problems with the athletes' ankles and knees in order to be able to run.

3.3. Experimental protocol

Each experiment began with identification of the ambient temperature on the athletic track average 28^{0}C (24^{0}-34^{0}C), mean humidity 77% (20% -96%), mean pressure 1011 mbar (1006 mbar-1016mbar), then the participants before the study had their body temperature measured using an infrared thermo gun and their body weight was measured before and after to determine the wasted acid using Accutrend Lactacid and their lactate analyser Lactic acid was taken 3 times, namely before and after 1600 meters of running activity, and after a 5 minute break. The participants were not allowed to drink during their 1600 run to ensure the same test protocol for each group. They were also equipped with a pulse meter (polar OH1 heart rate monitor).

3.4. Instrumentation and measured parameters

Measurements to all participants were divided into 3 groups wearing such different cooling vests as (CV-f50), (CV-f80) and (CV-f100). Their body temperature was taken at the forehead point, 10 cm away, measured by an infrared thermo gun and body weight (kg) was measured by a scale (Mi Body Scale composition 2, Xiaomi), their pulse was measured using a Polar (OH1 heart rate monitor), in which the polar was tied on the upper arm and monitored using the iPad (Apple) Polar Team data, recorded every 400-meter point. Measurement of lactic acid using Accutrend Lactacid with BM strips of lactic acid to store blood (+1ml) after the participants' fingertips were pierced using blood lancets, then the lactate strip was inserted and checked using Accutrend Lactate.

3.5. Statistical analysis

All the statistical analyses were performed with SPSS v26.0 for Windows (SPSS Inc., Chicago, USA). Paired sample t-test was to compare means and test significance between groups in all cases. Measurement of body weight, initial temperature, pulse, and lactic acid was performed using ANOVA analysis. In the meantime, the follow-up test used Fisher's LSD (least significant difference) because it was the simplest and most commonly used. Statistical significance was accepted at the level (p-value) <0.05.

4. Results

4.1. Body Temperature

Following is each group's body temperature measured before the study: group 1=36.75^{o}C $\pm$0.12; group 2=36.46^{o}C$\pm$0.06; and group 3=36.88^{o}C$\pm$0.19.

4.2. Body weight and body fluids

The average body weight of each group measured before the study was: group 1=65.54Kg$\pm$1.95; group. 2=68.25Kg$\pm$2.04; and group 3=66.85 Kg$\pm$1.06 and that the study was group 1=64.81$\pm$1.9; group 2=67.26$\pm$2.00; and group 3=65.83Kg$\pm$1.62. Data of their body weight before and after the treatment showed fluids, as they were not allowed to drink during treatment.

In terms of analysis of body fluid variance (LApre), there was no difference p 0.847> 0.05; (LApeak) there was a difference in LApeak p 0.054 <0.05, and there was a difference when the lactic acid level during recovery LArec p 0.025 <0.05 All the graphs of the participants' age, body weight, and temperature are presented in Figs. 3, 4, and 5.

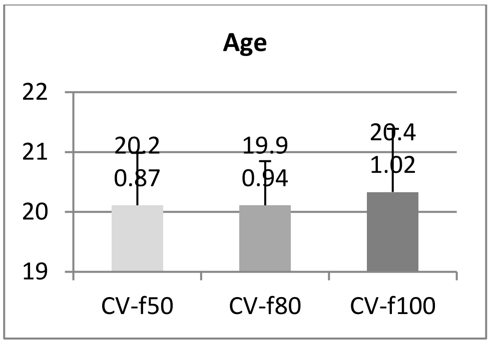

Fig. 3. Age of the participants.

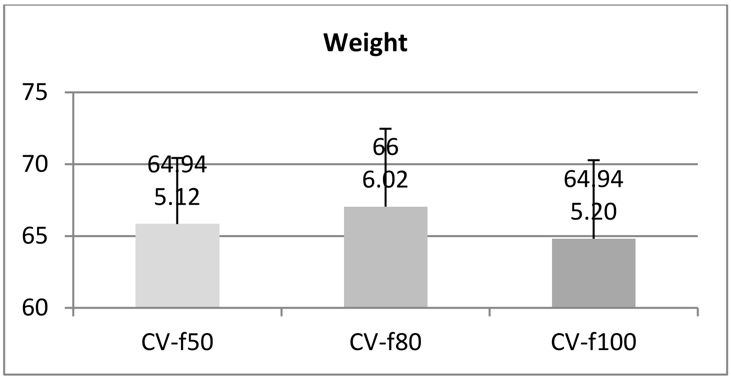

Fig. 4. Body weight of the participants.

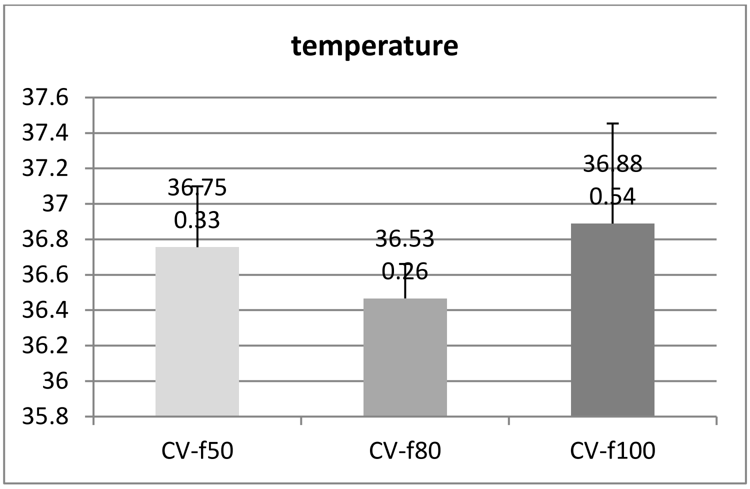

Fig. 5. Body temperature of the participants.

The fluids that came out showed a significant difference in group 1 and group 2 and those of group 1 and group 3. However, they showed no significant difference between group 2 and group 3 (as shown in Table 1). In the meantime, the participants were still able to tolerate the high number of the fluids coming out of their body, particularly those in group 3 (Table 2).

Table 1. Description of the fluid that came out after the experiment.

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Fluid loss	1.00	9	.7333	.21213	.07071	.5703	.8964	.40	1.20
	2.00	9	.9889	.19650	.06550	.8378	1.1399	.70	1.30
	3.00	9	.9222	.19221	.06407	.7745	1.0700	.70	1.30
	Total	27	.8815	.22194	.04271	.7937	.9693	.40	1.30

Table 2. Fisher's LSD advanced tests on body fluids.

Dependent Variable	(I) Experimental Group	(J) Experimental Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Fluid Loss	1.00	2.00	-.25556*	.09450	.012	-.4506	-.0605
		3.00	-.18889	.09450	.057	-.3839	.0061
	2.00	1.00	.25556*	.09450	.012	.0605	.4506
		3.00	.06667	.09450	.487	-.1284	.2617
	3.00	1.00	.18889	.09450	.057	-.0061	.3839
		2.00	-.06667	.09450	.487	-.2617	.1284

In Table 2, body fluids that come out after running activities on the use of a protein fiber-based cooling vest

4.3. Lactic acid

Following is the blood lactic acid average before the treatment group 1=3.94mMol / l + 0.44; group 2=3.67mMol/ l + 0.28; and group 3=3.88mMol/ l + 0.28. Meanwhile, that of each group after the treatment is group 1= 1.16.03mMol / l + 0.93; group 2=18.84mMol / l + 0.90; and group 3=19.04 + 0.95. Following is the recovery lactic acid level of each group: group 1=8.122mMol / l + 0.48; group 2=. 9.85mMol / l + 0.49; and group 3= 10.03 + 0.53. In terms of analysis of variance Initial lactic acid levels (LApre), there was no difference p 0.847> 0.05; (LApeak) there was a difference in LApeak p 0.054 <0.05, and there was a difference when the lactic acid level during recovery LArec p 0.025 <0.05

At peak conditions, the lactic acid of each group varies, especially between group 1 and group 2 and between group 1 and group 3. However, there is no significant difference between group 2 and group 3. The participants were still able to survive the 1600-meter run despite high lactic acid conditions, especially those in group 3 (Table 2). Meanwhile, in terms of lactic acid recovery after 5 minutes of rest, there was a significant difference between group 1 and group 2 and between group 1 and group 3 and there was not significant difference between group 2 and group 3 as presented in Table 3.

Table 3. Description of lactic acid.

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Initial lactic acid level	1.00	9	3.9444	1.32109	.44036	2.9290	4.9599	1.80	5.90
	2.00	9	3.6778	.85114	.28371	3.0235	4.3320	2.20	4.60
	3.00	9	3.8889	.85359	.28453	3.2328	4.5450	2.50	5.20
	Total	27	3.8370	.99890	.19224	3.4419	4.2322	1.80	5.90
Peak lactic acid level	1.00	9	16.0333	2.78837	.92946	13.8900	18.1767	12.10	20.70
	2.00	9	18.8444	2.70144	.90048	16.7679	20.9210	15.30	21.30
	3.00	9	19.0444	2.84346	.94782	16.8588	21.2301	14.70	21.50
	Total	27	17.9741	3.01466	.58017	16.7815	19.1666	12.10	21.50
Recovery lactic acid level	1.00	9	8.1222	1.46375	.48792	6.9971	9.2474	6.15	10.20
	2.00	9	9.8522	1.48410	.49470	8.7114	10.9930	7.75	11.30
	3.00	9	10.0333	1.61478	.53826	8.7921	11.2746	7.80	11.80
	Total	27	9.3359	1.70582	.32828	8.6611	10.0107	6.15	11.80

4.4. Pulse

The participants' pulse was measured 5 times with the following description. Group 1=120x / minutes + 6.82; group 2=125x / minutes + 5.83; group 3=134x / minute + 3.9; HR_{800} : group 1=181.6x / minutes + 1.96; group 2=178x / minutes + 1.54; and group 3=180x / minute + 31.71: HR_{1200} : group 1=185.11x/ minutes + 1.95; group 2=182.88x/ minutes+ 1.02; group 3=185.11x / minutes + 0.84; HR_{1600} : group=189.22x / minutes + 2.08; group 2=189.88x / minutes + 0.64; group=189.4x / minute + 0.42; pulse after a 5-minute rest HRrec: group=1. 86.33x / minutes + 1.04; group 2=89.66x / minute + 0.86; group=92.66x / minute + 1.19. In terms of analysis of variance HR_{400} there was no difference p 0.192> 0.05, HR_{800} p 0.347> 0.05; there was a difference in HR_{1200} p 0.096 <0.05, and at HR_{1600} there was no difference at p 0.898> 0.05

The pulse rate on the first lap was HR_{400}, showed that there was no significant difference between group 1 and group 2 yet there was a significant difference between group 1 and group 3 (Table 4). However, there was no difference between group 2 and group 3 and in $HR_{800,}$ there was no significant difference between group 1 and group 2 and that between group 2 and group 3; however, in HR_{1200} there was no significant difference between group 1 and group 2 and between group 1 and group 3. In terms of $HR_{1600,}$ there was no significant difference between group and group 2, between group 1 and group 3, and between group 2 and group 3. In HRrest there was a significant difference between group 1 and group 2, between group 1 and group 3, and between group 2 and group 3.

Table 4. Description of the pulse.

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
HR 800	1.00	9	181.66	5.87	1.96	177.15	186.18	171.00	192.00
	2.00	9	178.00	4.63	1.54	174.43	181.56	172.00	184.00
	3.00	9	180.00	5.12	1.70	176.06	183.93	171.00	189.00
	Total	27	179.88	5.25	1.01	177.81	181.96	171.00	192.00
HR 1200	1.00	9	185.11	5.86	1.95	180.60	189.61	175.00	196.00
	2.00	9	182.88	3.05	1.02	180.54	185.24	179.00	189.00
	3.00	9	187.33	2.78	.93	185.19	189.47	184.00	193.00
	Total	27	185.11	4.39	.84	183.37	186.85	175.00	196.00
HR 1600	1.00	9	189.22	6.24	2.08	184.42	194.02	176.00	197.00

	2.00	9	189.11	1.96	.65	187.60	190.62	185.00	192.00
	3.00	9	189.89	1.27	.42	188.91	190.86	188.00	192.00
	Total	27	189.40	3.71	.714	187.94	190.88	176.00	197.00
HR 5-minute rest	1.00	9	86.33	3.12	1.04	83.93	88.73	82.00	93.00
	2.00	9	89.66	2.59	.87	87.67	91.66	85.00	93.00
	3.00	9	92.67	3.57	1.194	89.92	95.41	88.00	99.00
	Total	27	89.56	3.99	.77	87.97	91.13	82.00	99.00

5. Discussion

The results of this study indicate that the use of cooling vests, especially those based on protein wool fibers, in medium-distance running activities (1600m) helps reduce fluid dehydration in the body. This is very important in athletic performance when training because the purpose of physical activity or exercise is to increase the athletes' ability. However, if there is a lack of fluids, it will be dangerous for health at any age since water is an important nutrient for the human body and is the main key to survival, one of which is by preventing dehydration [32]. Research activities in this study are also influenced by the condition of environment, loss of fluids in activities of at least 1-2% of body mass, accumulation of metabolites which remains constant, and core temperature which does not reach levels deemed important enough to be stopped because activity ranges from under 12 minutes. Metabolic control system is complex (central) which ensures that no physiological system (peripheral) is maximally utilized [33]. The use of protein wool fiber cooling vest in this study was shown to significantly reduce dehydration by taking into account the results of initial body weight and final body weight after weighing as other studies using cooling vest showed that the sweat rate was higher when using ice vests compared to control conditions when wearing vests made of common fabrics in the market such as polyester [34]. To provide a comfort effect, the ice contained in the cooling vest is on the front of the chest and upper back with a temperature of 18^0C; this condition suppresses sweat production and increases the sensation of wetness [35].

The convenience of using fibrous protein fiber cooling vests can also bring beneficial changes in physiological responses, where the body remains warm and moist, and the effects of neuromuscular and cardiovascular physiological responses and thermal responses that make the body feel fit [34]. The cooling vest used in this study was also assisted by an ice gel pack, the body temperature of around 36^0C was maintained with a wool-fiber cooling vest, and the protein fiber-covered cooling vest in this study used an ice pack. in the research of wool cloth its absorption capacity has been tested. Apart from having fiber strength, it also has shrinkage resistance [36]. Cooling vests use ice as a coolant, although Phase-Changing Materials (PCM) that melt at warmer temperatures have been used in an attempt to improve cooling by avoiding vasoconstriction [37].

The 1600 m running experiment was chosen because it is a physical activity with energy delivery systems (ergo-genesis in percentages) at oxidative 60%, glycolytic 35% and phosphagen 5%, which is in accordance with the energy requirements required for martial arts athletes [2]. During the match, which consists of 3 rounds, each round has 2 clean minutes [38]. The participants are considered to need this exercise in order to prepare for the competition. The findings obtained at peak lactic acid levels after 1600m running activity showed that there is a significant difference between the group using cooling vest and 100% with those using 80% fiber as well as 50%. However, there is significant difference between the 80% and the 50% groups. Likewise, in terms the lactic acid levels at recovery at 5 minutes of rest, there was a significant difference in the 100% with 80% and 50% groups, also there was no significance in the 80% and the 50% groups (Table 5). The finding is logical that there is a causal relationship between anaerobic metabolism and muscle fatigue as some of the consequences of anaerobic metabolism led to decreased contractile function. Anaerobic breakdown of glycogen causes intracellular accumulation of inorganic acids, of which lactic acid becomes quantitatively important [39]. Lactic acid that occurs is also related to Heart Rate (HR) so that this study also looked at the process on the pulse (HR).

Table 5. Fisher's LSD advanced tests on peak lactic acid and lactic acid recovery.

Dependent Variable	(I) Experimental group	(J) Experimental group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Peak lactic acid level	1.00	2.00	-2.81111*	1.30974	.042	-5.5143	-.1079
		3.00	-3.01111*	1.30974	.031	-5.7143	-.3079
	2.00	1.00	2.81111*	1.30974	.042	.1079	5.5143
		3.00	-.20000	1.30974	.880	-2.9032	2.5032
	3.00	1.00	3.01111*	1.30974	.031	.3079	5.7143
		2.00	.20000	1.30974	.880	-2.5032	2.9032
Recovery lactic acid level	1.00	2.00	-1.73000*	.71764	.024	-3.2111	-.2489
		3.00	-1.91111*	.71764	.014	-3.3922	-.4300
	2.00	1.00	1.73000*	.71764	.024	.2489	3.2111
		3.00	-.18111	.71764	.803	-1.6622	1.3000
	3.00	1.00	1.91111*	.71764	.014	.4300	3.3922
		2.00	.18111	.71764	.803	-1.3000	1.6622

To see the pulse rate (HR), running activity is selected. The 1600m running is considered in accordance with the needs of martial arts athletes. In addition to identifying an increase in pulse and recovery process, the pulse is monitored every 400 meters. It was found that there was no significant difference in the pulse rate at the first 400 meters in each group, as well as at 800 meters. However, at 1200 meters there is a difference between group 2 and group 3 while there was no significant difference between group 1 and group 2 and between group 1 and group 3 (Table 6).

The overall recovery process during exercise was not different. This is related to blood acidosis and arterial oxygenation (PaO2) which plays an important role in the chemoreflex control of working heart activity, the pulse after maximal exercise is associated with post-exercise increases in blood level (LA) and/ or resting PaO2 [40], so that in this study the resting Heart Rate (HR) was also seen. The findings obtained by HR rest after 5 minutes showed that there were significant differences in each group. The impact of the wool-fiber cooling vest was only seen at the time of HR rest as there was no difference between activities or recovery exercise, even though there were proves that group 2 and group 3 were different when in the 1200 meters.

The finding of a significant difference in HRrest is due to the fact HR Recovery (HRR) after exercise consists of two phases; fast and slow where the fast phase refers to the first minute of recovery (<1 minute) and characterizes a period in which there is a sudden and rapid decrease in HR. meanwhile, the slow phase refers to the period after the fast phase (> 2 minutes) [41].

Finally, the relationship between pulse and lactic acid seen in the use of cooling vest was seen in the recovery process in each group. At peak and rest length conditions, there were significant differences, but not significant in groups 2 and 3. This is most likely related to the polyester content on both the 80% and 50% protein fiber of the vest.

Table 6. Advanced test of fisher's LSD on heart rate.

Dependent Variable	(I) Experimental group	(J) Experimental group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
HR 400	1.00	2.00	-5.00	7.98	.537	-21.49	11.48
		3.00	-14.78	7.98	.077	-31.29	1.71
	2.00	1.00	5.00	7.98	.537	-11.49	21.49
		3.00	-9.78	7.98	.233	-26.27	6.71
	3.00	1.00	14.78	7.98	.077	-1.71	31.27
		2.00	9.78	7.98	.233	-6.71	26.27
HR 800	1.00	2.00	3.67	2.47	.150	-1.43	8.76
		3.00	1.67	2.46	.506	-3.43	6.76
	2.00	1.00	-3.67	2.46	.150	-8.76	1.43
		3.00	-2.00	2.46	.426	-7.09	3.09
	3.00	1.00	-1.67	2.46	.506	-6.76	3.43
		2.00	2.00	2.46	.426	-3.09	7.09
HR 1200	1.00	2.00	2.22	1.95	.266	-1.81	6.25
		3.00	-2.22	1.95	.266	-6.25	1.81
	2.00	1.00	-2.22	1.95	.266	-6.25	1.81
		3.00	-4.44*	1.95	.032	-8.47	-.41
	3.00	1.00	2.22	1.95	.266	-1.81	6.25
		2.00	4.44*	1.95	.032	.41	8.47
HR 1600	1.00	2.00	.11	1.81	.952	-3.63	3.85
		3.00	-.67	1.81	.716	-4.41	3.07
	2.00	1.00	-.11	1.81	.952	-3.85	3.63
		3.00	-.77778	1.81	.672	-4.52	2.97
	3.00	1.00	.67	1.81	.716	-3.08	4.41
		2.00	.78	1.81	.672	-2.96	4.52
HR 5-minute rest	1.00	2.00	-3.33	1.47	.033	-6.37	-.29
		3.00	-6.33	1.47	.000	-9.37	-3.29
	2.00	1.00	3.33*	1.47	.033	.29	6.37
		3.00	-3.00	1.47	.053	-6.04	.038
	3.00	1.00	6.33	1.47	.000	3.29	9.37
		2.00	3.00	1.47	.053	-.0380	6.04

6. Conclusions

The results of this study indicate that not only the peak conditions of exercise but also the long recovery process, in using a protein fiber-based cooling vest, during the heavy cycle of exercise, keeping the body warm and moist causes physiological adaptations that benefit *Pencak Silat* athletes which leads to a rapid process of thermal tension and physiologically, thereby improving the performance of *Pencak Silat* athletes. It is recommended that further studies put more focus on body temperature variables and the comparison between a fibrous cooling vest and a cooling vest without protein fiber.

Acknowledgment

The Ministry of Research, Technology, and Higher Education, Republic of Indonesia as well as Research and Community Service Center of Universitas Negeri Jakarta, Indonesia, are properly acknowledged for funding the research with letter No.4/SP2H/DRPM/LPPPM-UNJ/2017.

References

1. Yu, X. (2020). Fatigue and Recovery of Wushu Athletes Based on Fatigue Damage Model. *Proceedings of the 7th International Conference on Advanced*

Composite Materials and Manufacturing Engineering (ACMME 2020). Yunnan, China, 012016.

2. Bompa, T.O.; and Buzzichelli, C. (2018). *Periodization-: theory and methodology of training*. Champaign: Human kinetics.
3. Reilly, T.; and Ekblom, B. (2005). The use of recovery methods post-exercise. *Journal of sports sciences*, 23(6), 619-627.
4. Boguszewski, D. (2015). Application of physiotherapeutic methods to support training and post-exercise recovery of combat sports and martial arts contestants. *Journal of Combat Sports and Martial Arts*, 6(2), 85-90.
5. Lazic, J.S.; Dekleva, M.; Soldatovic, I.; Leischik, R.; Suzic, S.; Radovanovic, D.; and Mazic, S. (2017). Heart rate recovery in elite athletes: the impact of age and exercise capacity. *Clinical physiology and functional imaging*, 37(2), 117-123.
6. Brade, C.; Dawson, B.; Wallman, K.; and Polglaze, T. (2010). Postexercise cooling rates in 2 cooling jackets. *Journal of Athletic Training*, 45(2), 164-169.
7. Pooley, S.; Spendiff, O.; Allen, M.; and Moir, H.J. (2020). Comparative efficacy of active recovery and cold water immersion as post-match recovery interventions in elite youth soccer. *Journal of sports sciences*, 38(11-12), 1423-1431.
8. Zare, M.; Dehghan, H.; Yazdanirad, S.; and Khoshakhlagh, A.H. (2019). Comparison of the Impact of an Optimized Ice Cooling Vest and a Paraffin Cooling Vest on Physiological and Perceptual Strain. *Safety and health at work*, 10(2), 219-223.
9. Arngrïmsson, S.Á.; Petitt, D.S.; Stueck, M.G.; Jorgensen, D.K.; and Cureton, K.J. (2004). Cooling vest worn during active warm-up improves 5-km run performance in the heat. *Journal of applied physiology*, 96, 1867–1874
10. Mneimneh, F.; Ghaddar, N.; Ghali, K.; Moussalem, C.; and Omeis, I. (2019). Would personal cooling vest be effective for use during exercise by people with thoracic spinal cord injury? *Journal of thermal biology*, 82, 123-141.
11. Raad, R.; Itani, M.; Ghaddar, N.; and Ghali, K. (2019). A novel M-cycle evaporative cooling vest for enhanced comfort of active human in hot environment. *International Journal of Thermal Sciences*, 142, 1-13.
12. Itani, M.; Ghaddar, N.; and Ghali, K. (2017). Innovative PCM-desiccant packet to provide dry microclimate and improve performance of cooling vest in hot environment. *Energy Conversion and Management*, 140, 218-227.
13. Kenny, G.P.; Schissler, A.R.; Stapleton, J.; Piamonte, M.; Binder, K.; Lynn, A.; and Hardcastle, S.G. (2011). Ice cooling vest on tolerance for exercise under uncompensable heat stress. *Journal of occupational and environmental hygiene*, 8(8), 484-491.
14. Gauche, E.; Couturier, A.; Lepers, R.; Michaut, A.; Rabita, G.; and Hausswirth, C. (2009). Neuromuscular fatigue following high versus low-intensity eccentric exercise of biceps brachii muscle. *Journal of Electromyography and Kinesiology*, 19(6), e481-e486.
15. Knicker, A.J.; Renshaw, I.; Oldham, A.R.; and Cairns, S.P. (2011). Interactive processes link the multiple symptoms of fatigue in sport competition. *Sports medicine*, 41(4), 307-328.

16. Peiffer, J.J.; Abbiss, C.R.; Watson, G.; Nosaka, K.; and Laursen, P.B. (2009). Effect of cold-water immersion duration on body temperature and muscle function. *Journal of sports sciences*, 27(10), 987-993.
17. Hausswirth, C.; and Mujika, I. (2013). *Recovery for performance in sport.* Champaign: Human Kinetics.
18. Romadhona, N.F.; Sari, G.M.; and Utomo, D. N. (2019). Comparison of sport massage and combination of cold water immersion with sport massage on decrease of blood lactic acid level. *Proceedings of the 5th ICAMBBE (International Conference on Advance Molecular Bioscience and Biomedical Engineering).* Malang, Indonesia, 012012.
19. Kalli, K.; and Fousekis, K. (2019). The effects of cryotherapy on athletes' muscle strength, flexibility, and neuromuscular control: A systematic review of the literature. *Journal of Bodywork and Movement Therapies,* 24(2), 175-188.
20. Jinnah, A.H.; Luo, T.D.; Mendias, C.; and Freehill, M. (2019). Cryotherapy duration is critical in short-term recovery of athletes: a systematic review. *Journal of ISAKOS: Joint Disorders and Orthopaedic Sports Medicine*, 4(3), 131-136.
21. Fecchio, R.Y.; Brito, L.; Leicht, A.S.; Forjaz, C.L.; and Peçanha, T. (2019). Reproducibility of post-exercise heart rate recovery indices: A systematic review. *Autonomic Neuroscience*, 221, 102582.
22. Bleakley, C.M.; and Davison, G.W. (2010). What is the biochemical and physiological rationale for using cold-water immersion in sports recovery? A systematic review. *British journal of sports medicine*, 44(3), 179-187.
23. Halson, S.L. (2011). Does the time frame between exercise influence the effectiveness of hydrotherapy for recovery? *International journal of sports physiology and performance*, 6(2), 147-159.
24. Ückert, S.; and Joch, W. (2007). Effects of warm-up and precooling on endurance performance in the heat. *British journal of sports medicine*, 41(6), 380-384.
25. Webster, J.; Holland, E.J.; Sleivert, G.; Laing, R.M.; and Niven, B.E. (2005). A light-weight cooling vest enhances performance of athletes in the heat. *Ergonomics*, 48(7), 821-837.
26. Lubis, J.; and Suliyanthini, D. (2017). Cooling Vests Wool Fibre for Recovery Activity. International *Journal of Science and Engineering Investigations*, 6(69), 35–38.
27. Wang, X.; Zhao, Y.; Li, W.; and Wang, H. (2015). Effect of surface modifications on the thermal and moisture behavior of wool fabric. *Applied Surface Science*, 342, 101-105.
28. Johnson, N.A.G.; and Russell, I.M. (2008). *Advances in wool technology.* Amsterdam: Elsevier.
29. Allafi, F.A.S.; Hossain, M.S.; Ab Kadir, M.O.; Shaah, M.A.H.; Lalung, J.; and Ahmad, M.I. (2020). Waterless processing of sheep wool fiber in textile industry with supercritical CO_2: Potential and challenges. *Journal of Cleaner Production*, 285, 124819.
30. Shishoo, R. (2015). *Textiles for sportswear.* Amsterdam: Elsevier.

31. Camlibel, N.O. (2018). *Introductory Chapter: Introduction to "Polyester–Production, Characterization and Innovative Applications"*. London: IntechOpen.
32. Marcos, A.; Manonelles, P.; Palacios, N.; Warnberg, J.; Casajús, J. A.; Pérez, M.; and Urrialde, R. (2014). Actividad física, hidratación y salud. *Nutrición Hospitalaria*, 29(6), 1224-1239.
33. Edwards, A.M.; and Noakes, T.D. (2009). Dehydration. *Sports Medicine*, 39(1), 1-13.
34. Luomala, M.J.; Oksa, J.; Salmi, J.A.; Linnamo, V.; Holmér, I.; Smolander, J.; and Dugué, B. (2012). Adding a cooling vest during cycling improves performance in warm and humid conditions. *Journal of Thermal Biology*, 37(1), 47-55.
35. Ouahrani, D.; Itani, M.; Ghaddar, N.; Ghali, K.; and Khater, B. (2017). Experimental study on using PCMs of different melting temperatures in one cooling vest to reduce its weight and improve comfort. *Energy and Buildings*, 155, 533-545.
36. Smith, E.; and Shen, J. (2011). Surface modification of wool with protease extracted polypeptides. *Journal of biotechnology*, 156(2), 134-140.
37. House, J.R.; Lunt, H.C.; Taylor, R.; Milligan, G.; Lyons, J.A.; and House, C.M. (2013). The impact of a phase-change cooling vest on heat strain and the effect of different cooling pack melting temperatures. *European journal of applied physiology*, 113(5), 1223-1231.
38. Liskustyawati, H.; Mukholid, A.; and Waluyo, W. (2019). The Average Needs of Pencak Silat Basic Technique from Sparring Category. *International Journal of Multicultural and Multireligious Understanding*, 6(4), 308-313.
39. Westerblad, H.; Allen, D.G.; and Lannergren, J. (2002). Muscle fatigue: lactic acid or inorganic phosphate the major cause? *Physiology*, 17(1), 17-21.
40. Ba, A.; Delliaux, S.; Bregeon, F.; Levy, S.; and Jammes, Y. (2009). Post-exercise heart rate recovery in healthy, obeses, and COPD subjects: relationships with blood lactic acid and PaO 2 levels. *Clinical Research in Cardiology*, 98(1), 52-58.
41. Villelabeitia-Jaureguizar, K.; Vicente-Campos, D.; Senen, A.B.; Jiménez, V.H.; Garrido-Lestache, M.E.B.; and Chicharro, J.L. (2017). Effects of high-intensity interval versus continuous exercise training on post-exercise heart rate recovery in coronary heart-disease patients. *International journal of cardiology*, 244, 17-23.