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Research paper

Ice Bath Therapy on Athletes Recovery Response Using EEG

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Abstract

Sport recovery system is an integral aspect to help athletes adapt faster to training. This is an important process of physical preparation by reducing fatigue where the athletes can ready for the next competition or training. However, most of an athlete doing training without having the fully recovery after the training and can affect their performance. The cold bath water immersion is the one of common technique to recover from the fatigue. In this study, Neurosky mindwave is use to extract the brain wave of an athlete to know the response of an athlete when perform the cold water immersion. The responses of an athlete include meditation which is in alpha wave that state in relax condition and beta wave that is in fatigue condition in sport. The raw brain wave signal that extract using Neurosky mindwave is analysed using Matlab in terms of time domain. After that, Fast Fourier Transform (FFT) will use to analysed in terms of frequency domain. This project used alpha and beta band to collect the data. The analysis have made based on the peak value in frequency domain to know the best time for cold water immersion and best cold bath temperature.

Keywords: *Brain Wave; Cold Ice Bath Theraphy; EEG; Fatigue; NeuroSky Mindwave,*

1. Introduction

In sport, the athletes usually focusing into training and competition. The training that their focusing based on their schedule reduce the capacity in athletes performance. The regular training based on the schedule can cause muscle damage and it is the important factor that limiting the performance of the athletes [1]. It causes fatigue to an athlete and make them not able to perform well in their competition and follow the regime of training schedule.

Fatigue can be defined as a reduction capacity of the muscle reduction in the maximal force generating [2]. Physical fatigue can cause the temporary inability of muscle to perform optimally. The effect of fatigue on human are widely studied because of the sensorimotor function may decreased the functional joint stability, many muscle properties change during fatigue including the extracellular and intracellular ions. Besides that, action potential and many intracellular metabolites are affected. A range of mechanisms have been identified that contribute to the decline performance [3]. The performance of muscle is decrease when used in near maximum capacity.

Combination of reduced force production, slowed relaxation and decreased velocity of shortening will change the performance that lead to extreme reductions in performance particularly for rapidly repeated movements.The quality recovery is important to make sure the athletes in good shape and can perform well in training and competition. The quality recovery will indicate the good result in terms of restoring the physiological of an athlete. It will recover the fatigue, muscle damage and increase the performance for an athlete that can make the athletes always in good shape for their training

and competition [4]. Cold water immersion is the one of the recovery system for an athlete and it helps the recovery of the human body when react to water immersion. It will change in the heart, blood flow and muscle function [5].

Fatigue detection is an on-going research topic among both psychologists and engineers. Both of them are able sensors and bio signal processing technologies to be developed for detecting the human stress. There are few types of bio signal processing technologies use for human stress detection such as Electrocardiography (ECG), Electromyography (EMG), Electroencephalography (EEG), Blood Pressure (BP), Blood Volume Pulses (BVP) and Galvanic Skin Resistance (GSR) [6].

The reaction of an athletes towards recovery process can be identified by using EEG. EEG has been long used to know the reaction of human body based on the relationship among human and behaviour because of it delivers a direct real-time measure of neural activity. EEG are inexpensive and easy to apply because is recorded using electrode places at specific locations such as frontal, temporal, parietal and occipital in scalp [7].

Electroencephalography (EEG) signal is the most common of nature signals. The signal exists in the brains of human beings and animals. Table 1 shows the activities of EEG in for different signal of wave.

Table 1: The frequency and amplitude at different signal

Signal	Frequency, (Hz)	Amplitude, (μV)
Delta,δ	Less than 4	20-200
Theta, θ	4-8	Around 20

Alpha, α	8-15	20-200
Beta, β	15-40	5-10

It records the brain wave pattern from the signal produces. From ionic current, the EEG will measure the inconstantly voltage establish from internal neurons of the brain. In clinical condition, EEG show the chronicle of the mind's unconstrained electrical movement over a period, as recorded from numerous anodes put on the scalp [8].

Muscular pain usually comes after unaccustomed or eccentric exercise and is usually defined as delayed onset muscle soreness (DOMS). DOMS cause reduced range of motion and decrease in capability of muscle to produce force. It also causes pain that is exacerbated by movement. The typical symptoms of DOMS are muscle tenderness, stiffness, strength loss, swelling and pain. The peak of muscle soreness can be felt around 24 to 72 hours and the resolution of symptoms can long to 5 to 7 days [9].

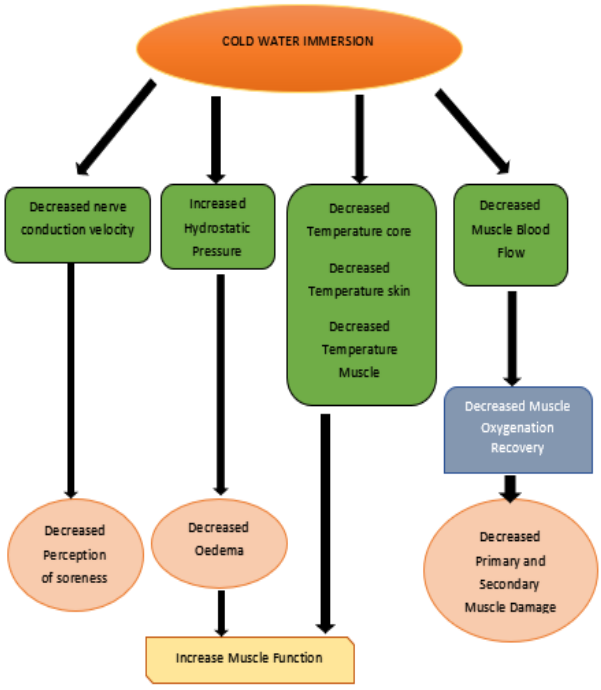

Fig. 1: Physiological effect of cold water immersion [13]

Over the past decade, cold water immersion (CWI) is a technique and the most popular strategies to prevent and manage DOMS and use in post-exercise recovery. CWI becomes popular because of it can perform in different situations and low-cost techniques [10].

Based on endurance exercise, studies have shown that cold water immersion reduces the blood flow to the limbs and muscle. Endothelin is peptides that constrict blood vessels and raise blood pressure has been implicated in vascular responses to cold exposure. Therefore, muscle and limb blood flow regulated after cold water immersion applied. The temperature of muscle after endurance exercise also reduces after cold water immersion apply [11]. The metabolic activity and muscle blood flow reported decrease when applying cold water immersion [12]. Cold water immersion has also been proposed to reduce inflammation from exercise [11]. Figure 2.9 shows the physiological effect of cold water immersion [13].

2. Experimental Set Up

Experiment is started with before the workout, EEG signal wave for meditation is taken using Neurosky mindwave for 5 minutes. After that, athlete start the workout routine and after finish the workout routine, EEG signal wave for meditation is taken again for another 5 minutes for reading after workout. Then, athlete will perform the cold bath water immersion for 15 minutes. There have three experiments for each athlete. Each athlete will repeat three different temperature which is 13°C, 14°C and 15°C. The reading for data will take at 11 minutes, 12 minutes, 13 minutes, 14 minutes and 15 minutes.

In this study, there are few types of equipment used to conduct the experiment. The equipment is divided into tools, hardware and software which use to extract the data. The tools that used for cold water immersion therapy for an athlete are bath tub, chiller Hailea HS-90A, water pump and rubber pipe. MATLAB is the software used to retrieve data from hardware used which is NeuroSky Mindwave.

2.1. Hardware and software stage

The hardware involves experimental components, Neurosky Mindwave device and the software uses MATLAB R2015. Figure 3.6 shows the components set up for experiment. The water pump is located inside the bath tub and below the water level. The water pump is connected with rubber pipe and the other end rubber pipe will connect with inlet at Chiller Hailea HS-90A. Another rubber pipe with connect with the outlet of Chiller Hailea HS-90A and the other end is put inside the bath tub. For this experiment, make sure that no water leakage from the rubber pipe connections. Before starting the chiller, the pump must be run and make sure that there is water in the bath tub. After that, set the required temperature.

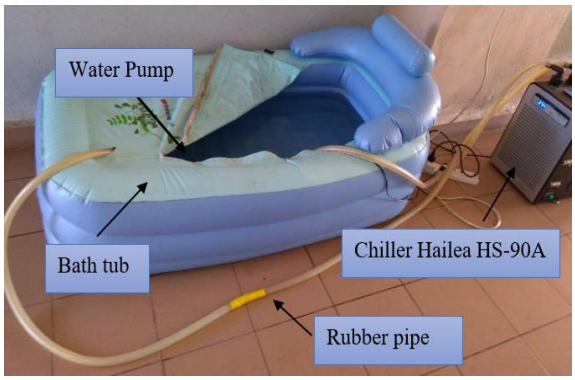

Fig. 2: Components set up

Meanwhile, the Neurosky Mindwave device will take the electrical wave that produces by the brain. EEG signal have a specific signal frequency that can be divided into two condition that are waves or rhythmic patterns. The frequency response measured in Hertz (Hz) or cycles per seconds generates different type of brain wave pattern that is delta, theta, alpha, beta and gamma. This study aims to study the response of athlete after applying the cold water immersion.

Based on the Cheron et al., 2016,[14] know that the person will feel fatigue after perform sport and it will generates Beta (β) wave which is in 15-30 Hz and the person when relax and resting state is alpha (α) wave which in 8-15 Hz. The electrical wave that form from the response of a person brain of Neurosky mindwave will extract in total waves. It need to classify which type of the frequency wave occurs. From that, the wave pattern can see whether delta, theta, alpha, beta and gamma. The result will show whether the athlete is recover or not after performing the recovery system which is cold water immersion and the result obtained will be tabulated on.

2.1.1. MATLAB Software

MATLAB software will be used to interpret the data that been extract by NeuroSky Mindwave. MATLAB is developed by

MathWorks and it is a multi-paradigm programming language numerical analysis. This software is written the different language of program such as C, C++, Java, and Python to interfacing the program, plotting of data and function, implementation of algorithm and creation of user interfaces.

The technology of thinkgear inside NeuroSky enables it to interface with the wearers brainwaves and responsible for directing headset data from the serial port to an open network socket. The thinkgear connector runs a background process on the computer and process all the data. It also provides the data to software and applications in digital form using thinkgear module that contains the onboard chip.

MATLAB software allows the sign is taken from NeuroSky Mindwave to be displayed and analysed using this software. The communication protocol between MATLAB and Mindwave EEG device is illustrated in Figure 3.7. First, ThinkGear.dll file need to uploaded into Matlab. Connection between Mindwave and Matlab is established with using com port. After that, use the *TG_ReadPackets* function with ID parameter and number of packet to read to read a Packet of data from the connection. Then use *TG_GetValue* function to get the updated value of the raw EEG signal. Afterwards, can read the value of raw EEG signal. After finish, close the connection and unload ThinkGear.dll.

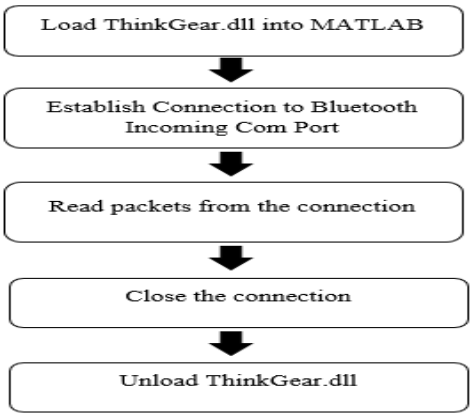

Fig. 0: Communication protocol of MATLAB and Mindwave

2.2. Fourier analysis

The extraction data of EEG signal comprises the sum of brainwave response or pattern signals. Raw data signal need to change to time domain. This total brainwave signal are extracted in time domain.The time domain signal represented by waveform where the analysis is mainly based on the voltage – time plot. The variable is always measured against time in time domain analysis. Its operation is not very useful or effective in signal processing. In this case, Fast Fourier Transform will be used to observe unhidden means of the signals.

Fast Fourier Transform is one of the technique that can be used to convert the signal from time domain to frequency domain. In Matlab, the coding NFFT and FFT algorithm has implemented. The signals in time domain comprises different signals of time which can be observed clearly as the peak in frequency domain. Thus, brainwave patterns at certain frequency range can be clearly analysed using the highest peak in frequency compared in time domain.

2.3. EEG data extraction to frequency domain

The NeuroSky mindwave headset was used to allow the data collection when the headset connects with ThinkGear software. Based on Figure 1 shows the raw data that had been collected using Neurosky mindwave. After that, Matlab software used to classified and extracted the data from NeuroSky Mindwave headset. The data then will be filtered again into different time domain range at different frequency as shown in Figure 2. Time domain are difficult to analyse and need to transform into frequency domain. The Fast Fourier Transform (FFT) will be used for the features extraction to convert the raw data EEG in time domain to frequency domain. The FFT method is important because the raw data signal need to split into the different frequency bands which alpha band and beta band as shown in Figure 3.

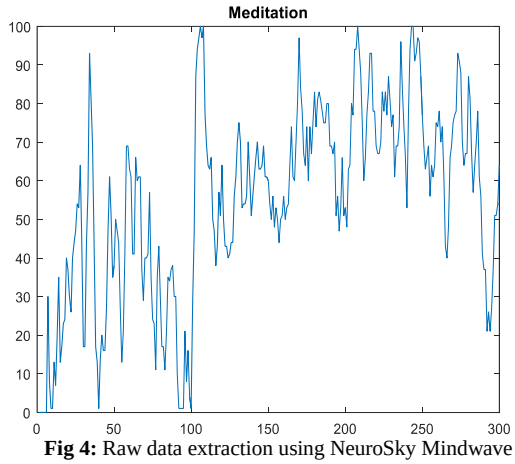

Fig 4: Raw data extraction using NeuroSky Mindwave

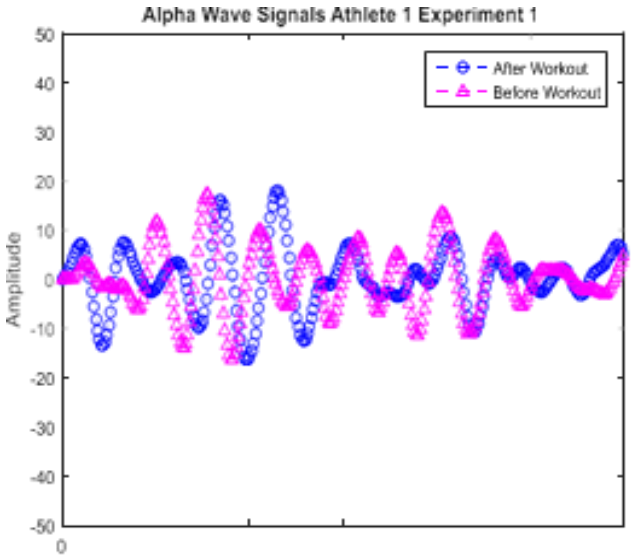

Fig 5: Filtered data in time domain

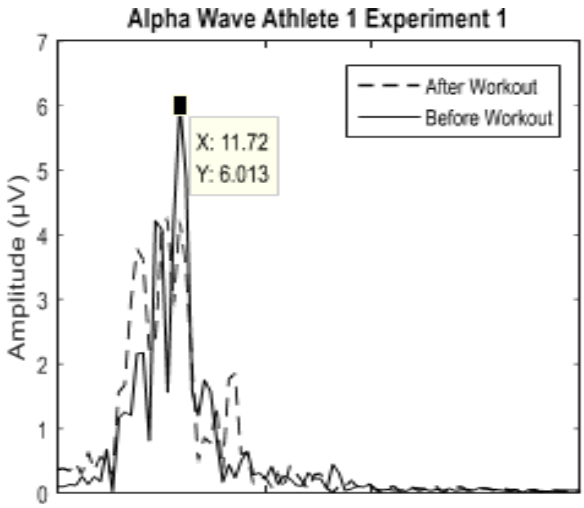

Fig. 6: Filtered data in frequency domain using FFT

3. Results and Discussions

3.1. Before and after workout

The reading before workout experiment was conducted before the athletes performed the workout routine. The reading of brain wave was taken for the 5 minutes before the athletes start the workout. After that, the athlete will start the workout followed the routine and after finish all the workout routine. The brain wave was taken again for the reading after workout for another 5 minutes.

Table 2 summarizes for all athletes (professional, intermediate and beginner) results for different immersion cool bath temperature of 13, 14 and 15°C. The purpose of the observation is to distinguish brain wave signal before and after workout among the athletes. It is to know the response of an athlete before and after workout.

Table 2: Summary of graph before and after workout

	Temp (°C)	Beta (β)		
		Before Workout (μV)	After Workout (μV)	Percentage (%)
Athlete 1	13	7.259	8.33	12.85
	14	3.447	4.466	22.82
	15	6.077	6.892	11.83
Athlete 2	13	5.136	5.712	10.08
	14	3.738	4.105	8.94
	15	4.597	6.210	25.97
Athlete 3	13	5.087	5.552	8.38
	14	6.075	7.740	21.51
	15	5.030	5.664	11.19

These show all athletes experienced increasing of beta wave after workout exercise when compared with before workout. From the result, the reading of EEG shows that response in beta wave is increased after perform the routine of workout. It show that the athlete feel fatigue after perform the workout.

3.2. Cold water immersion

Table 3 shows that the result of the highest alpha based on different time and temperature. From the analysis that have been conducted using the Matlab to find the best temperature and time for an athlete. The analysis was conducted with find the highest alpha wave that means of relaxed. Based on the analysis using Matlab, find that there have 3 different time with different temperature that form the highest alpha value based on different athletes as shown in Table 3.

From that, the analysis conducted again to find the best alpha value based on the athletes and it shows the result for athletes 1 for perform the cold water immersion is between 13 minutes to 15 minutes. However, the best cold water immersion is at cold bath temperature 14°C with cold water immersion 14 to 15 minutes for the athlete 1.

For athletes 2, the best alpha value for perform the cold water immersion is between 12 minutes to 14 minutes. It different between athlete 2 in terms of cold water immersion time but the reason for the different time for the water immersion is it because different people react differently based on their body and the activity. The best time for athlete 2 also at the temperature 14°C and for the cold water immersion is 13 to 14 minutes.

Then, for athletes 3 the best temperature to perform cold water immersion is at 14°C with 13 to 14 minutes cold water immersion same with athlete 2. However, the result shows at the cold bath temperature 15°C, the best alpha value is at 11 minutes to 12 minutes cold water immersion. Based on the experiment, the reading shows the different from expected. It may because of the condition when conducted the experiment which is that time is raining so the athlete recover early than the expectation because response with the environment condition.

Table 3: The highest alpha wave in cold water immersion

Athlete	Cold bath Temperature (°C)	Time (minutes)	α, μVolt
1	14	14-15	7.423
2	14	13-14	8.917
3	14	13-14	9.596

3.3. After workout and cold water immersion

The reading after workout experiment was conducted after the athletes performed the workout routine. The reading of brain wave was taken for the 5 minutes after the athletes finish the workout. After that, the athlete will performed cold ice bath therapy for the 15 minutes. In this result, only the best time are chooses to know the response of an athletes in the beta wave.

The result is summarised for all athletes (professional, intermediate and beginner) at 14°C cold bath water immersion which is the best cold bath temperature. The purpose of the observation is to distinguish brain wave signal after and during performed cold bath among the athletes. It is to know the response of an athlete after and during perform cold bath water immersion.

Based on Table 4, it shows that the athletes are feel fatigue after perform the workout. The highest peak value shows in beta frequency is after workout for the athlete 1,2 and 3. It can conclude that the athletes are tired or fatigue after the routine of workout and when performed the cold water immersion, the fatigue are reduced as shown the beta wave is higher at after workout than when performed the cold bath.

Table 4: Summary of graph after workout and cold bath

Athlete	Temp (°C)	Beta (β)		
		After Workout (μV)	Before Workout (μV)	Stress Relieve (%)
1	14	4.884	4.536	7.13
2	14	6.510	4.144	36.34
3	14	5.713	5.053	11.55

4. Conclusion

This project applied Neurosky Mindwave to know the recovery response of an athletes when perform ice bath therapy which is one of the recovery technique after the exercise. The Neurosky Mindwave is used to extract the brain wave in raw data and Matlab software is used to evaluate the raw data signal that produced by athletes. The data is evaluated in time domain and frequency domain, the wave bands that evaluated in this project is alpha wave and beta wave.

The study was conducted to know the response of athlete before the exercise and after the exercise. Besides that, it also determines the best temperature when performed the cold bath and the best time for cold water immersion. For the response of the athlete, the peak value in alpha wave is higher before exercise. This shows that the person is in relaxed condition. After the exercise, the response of data show the beta wave indicates the athlete is in fatigue condition. For the best temperature to performance cold bath based on this experiment is 14°C and the best time is between 13 minutes to 15 minutes.

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