EFFECT OF LOW-INTENSITY UNDERWATER EXERCISE ON THE RATE OF RECOVERY FROM EXERCISE-INDUCED MUSCULAR FATIGUE

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Abstract. This study investigated how elite basketball players' fatigue-related physiological indicators during acute recovery were affected by low-intensity underwater exercise technique. The study included 16 elite male basketball players who have participated in competitions at the all-India or national levels for at least four years. Each participant completes an exercise routine designed to cause muscular fatigue, followed by three distinct recovery techniques, passive recovery (PR), active recovery (AR) and underwater exercise technique (UET). Dependent variables were heart rate, lactate, and oxygen saturation (SPO2). A two-way repeated measures ANOVA was used to determine the effects of recovery techniques on dependent variables at different time points of recovery. Results show that AR and UET are significantly better than PR in terms of returning heart rate to normal. Lactate clearance rates were similar for AR and PR at the 10 min mark, but AR was significantly better compared to PR at the 20 min mark, and UET was significantly better than both AR and PR at the 10 min and 20 min markers. Oxygen saturation comparison reveal that there was no significant difference among recovery techniques and each recovery method exhibits a consistent SPO_2 recovery pattern. In conclusion, the study establish that that low-intensity underwater exercise is an effective technique for recovering from exercise-induced fatigue.

Keywords: Active recovery, Passive recovery, SPO_2 (oxygen saturation), Low intensity underwater exercises, Blood lactate.

INTRODUCTION

Basketball is an infrequent, court-based team sport that consists of repetitive high-energy movements such as changing direction, accelerations, and decelerations mixed with intervals of low to moderate intensity activities. (1) Basketball competition demands were investigated using time motion analysis (TMA), and the results showed that both male and female athletes travelled an average distance of 5–6 km throughout the course of 40-minute games. (1) In a basketball game, jumps happen more frequently than in other team sports, every minute, on average.(2) (3) Basketball players also engage in a lot of running and intense shuffling (2), which stresses the necessity of making consistent maximal efforts throughout match. Athletes compete at an average physiological intensity above lactate threshold and 85% of their maximal heart rate, according to physiological characteristics such blood lactate and heart rate responses to competition demands. (1) Toward the end of basketball game significant decrease in physical capacity of players and greater dependency on glycolytic energy system was observed. Elevated blood lactate indicates that fast glycolysis was the major contributor for energy needs, HR responses throughout that match indicated toward use of aerobic energy pathway. (4)

Exercise with a high eccentric loading is connected with myofibrillar material disruption and cytoskeleton damage. (5) Jumping power has been observed to be reduced by plyometric or eccentric leg pressing exercises, (6) (7) probably due to triggered muscle injury that reduces the number of functional motor units. Muscular fatigue can be categorized into 2 parts peripheral fatigue and central fatigue. Peripheral fatigue is described as a decrease in the neuromuscular junction's functioning as well as processes outside of the neuromuscular system, such as metabolic and biochemical alterations in the muscle. Here the homeostasis of the neuromuscular system is disrupted by the buildup of numerous circulatory metabolites. Among them blood lactate measurement is the most reliable and easiest method to quantify fatigue. (8)

Over the last 2 decades players uses number of recovery techniques, such as cold-water immersion, (9) active recovery, contrast water therapy, massage, uses of compression garments (CGs) (10) etc. which enhance the rate of recovery from fatigue. Among them active recovery and cold-water immersion (CWI) are most popular, active recovery facilitates faster clearance of circulatory metabolites by increasing blood flow to the muscles, which helps with the removal of metabolic waste and may reduce soreness and inflammation in the muscles. (11) The benefits of CWI on recovery can be explained through serval mechanism, a significant reduction in muscle inflammation and damage was observed after using CWI, (12) the depth of immersion and the temperature of the water may both aid in reducing the development of oedema and discomfort after strenuous activity, (9) hydrostatic pressure may facilitate the movement of fluids from the muscle to the circulation and so removing metabolites, vasoconstriction brought on by cold temperatures may also decrease fluid diffusion into the interstitial space and locally diminish the inflammatory response.

Another well-known method that has illustrated a significantly faster recovery rate from lactate accumulation is wearing compression garments (CG). CG creates an external pressure gradient that, can reduce the space available for swelling, haemorrhage, haematoma formation and provide mechanical support to muscles which reduces muscle inflammation after strenuous exercise that causes soft tissue injury. (5) Increasing the external pressure placed on the skin increases the venous return as well as the epidermal blood flow in the affected area. (13) The elimination of waste products and restoration of normal blood gas levels are thought to be aided by this increase in blood flow.

Performing low intensity exercises underwater water can provide benefits of active recovery, cold water immersion and compression garments simultaneously. Similar to compression garments, hydrostatic pressure increases venous return with fluid shift and induces the typical Frank-Starling reaction.(14) (15) Previous research indicates that there is a large increase in stroke volume (SV) and cardiac output, as well as an increase in end-diastolic volume (40–70 mL; around 46% of normal). Since the subject's body is submerged underwater and low-intensity exercise is performed there, the physiological benefits of CWI as well as active recovery can be utilized at same time for a quicker recovery from fatigue. Other potential advantages of performing exercise underwater are include increased balance, improved muscles strength caused by overcoming water resistance,(16) and exercise movement will be facilitated by the buoyancy and hydrostatic pressure of the water, which reduce the musculoskeletal compression forces compared to the normal environment.(17)

Despite having significant physiological effects that aid in fatigue recovery, low intensity underwater exercises have not yet been investigated as a recovery technique. This study aims to determine how low intensity underwater exercise impacts the rate of recovery from exercise-induced muscular fatigue.

METHOD

A total of 16 male basketball players from various universities and states agreed to take part in the study; all participants had competed in tournaments at the all-India or national levels for at least four years and had regularly trained for at least six sessions per week, descriptive data presented in Table 1. The selected participants were informed about the experimental procedures and precautions and requested to sign an informed consent form.

For the duration of the experiment, participants were told to follow their regular training schedule and refrain from taking part in any additional training sessions. Using any ergogenic aids was also restricted.

TABLE 1. Descriptive data for subjects (n=16)

VARIABLE	MEAN ± SD
Age (years)	22.6 + 2.8
Height (cm)	189.9 + 9.6
Weight (kg)	88.5 + 11.6
VO_2 max (ml/kg/min)	51.7 + 5.2
BMI	23.8 + 2.2

Experimental Instruments

Heart Rate: The heart rate was measured using a waterproof polar H10 heart rate sensor with an adjustable chest belt (pedometer) that included the transmitter, and the readings were in beats per minute.

SPO_2: The saturation of oxygen in blood was monitored using oxyline plus 9 pro-oximeter at various time intervals throughout the experiment, and the saturation of oxygen was expressed as a percentage of oxygen in hemoglobin.

Blood Lactate: The lactate concentration in blood was measured using a lactate scout 4 blood lactate analyzer, which provides a measurement in mg/dl.

Experimental Protocol

Exercise protocol for inducing fatigue

All subjects were told not to engage any physical activity and not to drink anything other than water before 8 hours of exercise. Prior to exercise, a baseline of physiological variables was collected. All exercise sessions were completed in the early morning; the exercise program was executed on a resistance bicycle ergometer and was identical for each subject. The workout program consists of four repeats of 20 seconds of near-maximal (> 90%) intensity bicycle pedaling with a two-minute rest interval between each repetition. During the exercise, HR and SPO2 were measured simultaneously, and lactic acid was measured within 2 minutes after the exercise concluded, and subjects were randomly assigned to different recovery methodologies.

Experiment protocol for recovery modalities

All subjects undergo 3 different recovery modalities, passive recovery, active recovery and underwater exercise technique. Time period between 2 experiment session for each subject was one week.

Active recovery: For the active recovery program, the participant pedaled on a bicycle ergometer for 20 minutes at an intensity of 35-40% of HRmax.

Underwater exercises: Subjects for the underwater workout recovery program entered the swimming pool wearing swimsuits and proceeded to the level where their entire body was immersed in water except for their heads. Walking, leaping, squatting, step-ups, and other actions of both limbs were performed by the subject in order to maintain a 30%-35% intensity of HRmax. Subjects performed the following program for 20 minutes.

All physiological variables were measured using standardized equipment at 10 and 20-minute intervals after beginning the recovery procedure.

Statistical Analysis

IBM SPSS Statistic version 22.0 for Windows was used for statistical analysis. The Kolmogorov-Smirnov test was used to validate normality assumptions(18) prior to conducting any statistical analysis. The two-way repeated measure analysis of variance (ANOVA) was performed to investigate how the recovery procedures and subsequent time intervals affect the selected physiological variables simultaneously. Further one-way repetitive measure ANOVA is used to analyze the simple effect of both components (recovery strategy and time interval). The exact differences are determined by performing a pairwise comparison (with Bonferroni post hoc adjustment) of the means of each physiological characteristic. Data are provided as mean value ± standard deviation, and p-values are regarded as statistically significant at $p \leq 0.05$.

RESULT

The changes in physiological variables after using different recovery modalities are illustrate in table. 2.

Heart rate measurement shows significant main difference at both levels, technique (T) and time points (TP), ($p \leq 0.05$) it also shows significant interaction effect of both T x TP ($p \leq 0.05$), while checking for simple effect of techniques, we find out that recovery rate for techniques significantly differ at 10mins, and 20 mints of time points, further comparison of means reveal that AR and UWT shows significant better recovery rate that PR, ($p \leq 0.05$) whereas AR and UET performed similarly at 10 minutes and 20 minutes into recovery time.

Blood lactate measurements show a significant main difference at T and TP as well as a significant interaction effect of T x TP. ($p \leq 0.05$) When simple effects were tested, blood lactate clearance at 10 and 20 minutes into the recovery period showed a significant difference ($p \leq 0.05$). When comparing the means of the

various recovery modalities, there is no difference between the blood lactate clearance rates of AR and PR at 10 minutes, AR had a significantly higher lactate clearance rate than PR at 20 minutes, ($p \leq 0.05$) and UET program performs significantly better blood lactate clearance than both AR and PR program ($p \leq 0.05$) at 10 mins as well as 20 mins into recovery time.

The SPO2 measurement reveals no significant main difference for T but shows a significant main difference for TP and a significant interaction effect for T x TP, both of which are statistically significant. ($p \leq 0.05$) Further analysis of the simple effect reveals that there is no significant difference in the SPO2 recovery rate among recovery modalities at any given time point. The significant interaction effect is only brought about by the mean difference of each recovery technique at various time points.

Table 2: Change in physiological variables during recovery process

Variable	Recovery Modality	Source	F-Value	Test			
				Pre-test	Post-test	10 min	20 min
Heart Rate	PR	Technique (T)	7.964*	69.18±5.82	140.36±4.20	115.29±6.55	96.05±5.74
	AR	Time point (TP)	1384.55*	69.31±6.90	139.25±4.90	99.0±2.20$^{\#}$	82.50±4.60$^{\#}$
	UET	T x TP	6.402*	68.12±6.08	136.37±4.50	92.87±7.85$^{\#}$	77.81±6.64$^{\#}$
Blood Lactate	PR	Technique (T)	118.62*	2.65±0.57	11.09±0.38	9.97±0.74	8.23±0.81
	AR	Time point (TP)	2718.58*	2.22±0.32	10.40±0.53	9.46±0.34	6.87±0.38$^{\#}$
	UET	T x TP	57.853*	2.28±0.29	10.21±0.50	7.61±0.63$^{\$\#}$	4.87±0.42$^{\$\#}$
SPO_2	PR	Technique (T)	1.340	98.54±0.45	94.73±0.79	96.99±0.92	98.23±0.46
	AR	Time point (TP)	212.69*	98.81±0.40	94.81±0.98	96.62±0.88	97.93±0.68
	UET	T x TP	2.367*	98.62±0.50	95.06±0.85	96.43±0.96	97.93±0.68

MEAN ± S.D., *: $p \leq 0.05$, $: significantly different from AR, #: significantly different from PR, UET: underwater exercise technique, PR: passive recovery, AR: active recovery

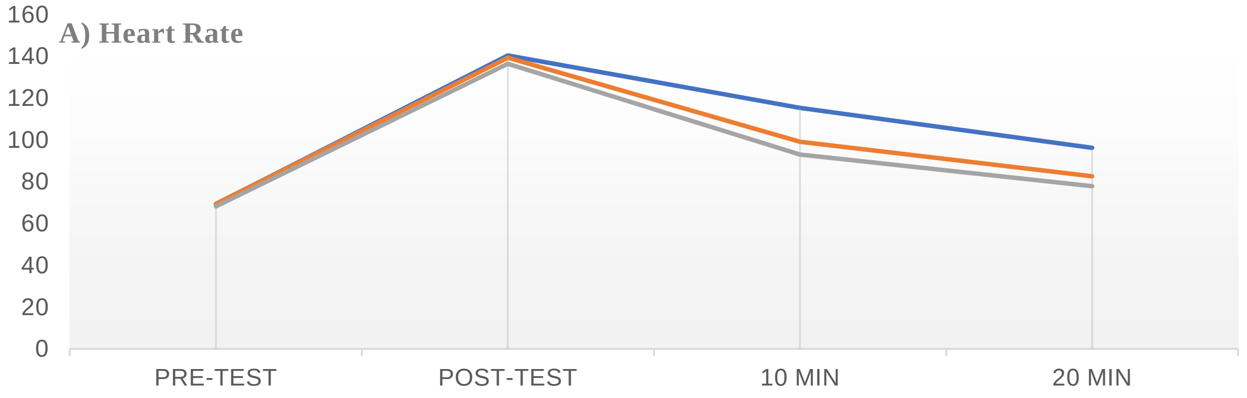
DISCUSSION

Muscular fatigue is caused by moderate to strenuous exercise, and full recovery from the fatigue state is necessary for elite performance. This study aims to determine whether low-intensity underwater exercises was more effective recovery approach as compared to other recovery methodologies like active recovery, compression garment, water immersion etc. We compare passive recovery (PR), active recovery (AR) and underwater exercise technique (UET) for different physiological variables to recovery phase. The exercise protocol used in this investigation was sufficient to induce muscle fatigue and significantly increase blood lactate and HR, while SPO2 was significantly reduced, previous studies performed on college students (19) and men's and women's elite basketball players, (2) (20) (21) show similar results. When we used two-way repeated measures ANOVA, the same group of athletes were tested under different recovery techniques, the measurement of physiological variables at pre and post-test gave similar results which proves that athletes perform identical in all 3 recovery techniques and no carryover effect was observed, thus any difference in measurement of variables at 10 min and 20 min into recovery was brought on by the recovery technique used.

Monitoring players heart rate during competition or training session provides objective information regarding physiological stress of the player and intensity of the exercise, in this experiment heart rate increased dramatically during the exercise protocol, observing HR for next 20 min into recovery reveal that AR and UET perform better than PR at bringing heart rate back to normal. (figure 1;A) The advantages of AR above PR have been well established for 30 years, and a vast amount of prior research demonstrates that AR can enhance blood supply to the muscles as a quick response. (22) (11) (23)

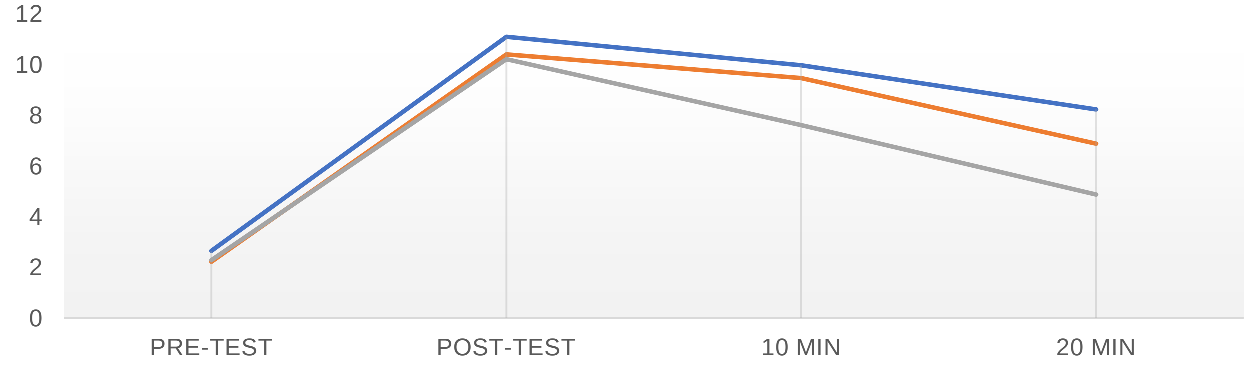
There was no significant difference between AR and UET in heart rate recovery at any time point. Though the heart rate was similar it may possible that UET was more efficient compared to AR in blood circulation because previous studies reported that heart rate decreased with water immersion. (24) (25) (26) They explain that a decrease in heart rate is accompanied by an increase in stroke volume (SV). The increase in SV occurs due to increased venous return, which is driven by hydrostatic pressure. It is therefore likely that the cardiovascular responses shown in this study were largely influenced by the hydrostatic pressure due to deep immersion. In addition, these studies have shown that heart rates are also lower when exercising in water than on land, both of which expend the same amount of energy. Recent study on this topic shows that cardiac size increases by 30% within 6 seconds of water immersion. (17) Cardiac preload (vein return) increases with this fluid change and leads to the classic Frank-Starling reflex. This reflex is an intrinsic mechanism of the heart that responds to elongation of myocardial fibers by increasing cardiac contractility. (27) Increased end-diastolic volume (40–70 ml; approximately 46% normal) increases myocardial fiber length. (28) With respect to a decrease in peripheral resistance, there is a significant increase in stroke volume (SV) and cardiac output. Increases in SV from 25% to 40% and cardiac output from 26% to 32% have been reported. (28)

Therefore, it is probable that even though the heart rates in AR and UET were identical, UET circulates more blood to muscles with less joint stress and muscular pain.



A) Heart Rate

B) Blood Lactate



C) SPO$_2$ (oxygen saturation)

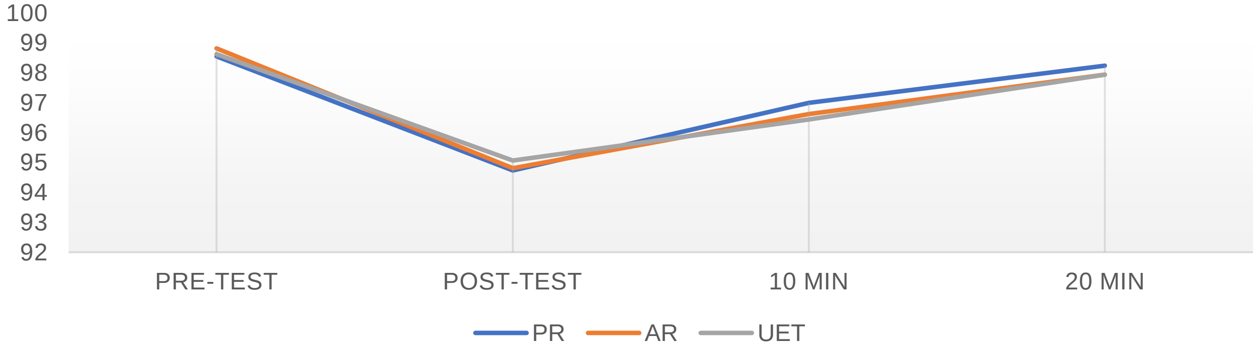


Figure 1. Measurement of all physiological variables, graph (A) shows the measured heart rate during different recovery technique across time points, graph (B) shows blood lactate measurement and graph (C) shows SPO$_2$ measurement.

Graphical representation of SPO$_2$ in figure .1 (C) shows that oxygen saturation decreases due to exercise. There was no significant difference among recovery techniques and each recovery method after exercise exhibits a consistent SPO$_2$ recovery pattern, and full SPO$_2$ recovery occurs in around 20 minutes. These results are consistent with those of other studies that track SPO_2 during intense exercise (29) or make use of various recovery techniques. (30) This is largely facilitated by the high oxygen availability and significant post-exercise rise in muscle blood volume. When exercise intensity exceeds the anaerobic threshold, lactate, a powerful anion, accumulates in skeletal muscle. This causes the intramuscular pH to drop as a result of the dissociation of H_2O into H^+ and OH_2 to maintain electroneutrality. (8) (31) The accumulation of hydrogen ions and the resulting acidosis environment can cause a decline in performance by preventing optimal muscle contraction (8) and by activating III and IV afferent receptors, which can affect muscle activation and motor control. (32)

Lactic acid removal can be enhanced both by stimulating its oxidation by previously working muscles and by increased blood flow to other parts of the body and increased oxidation by previously inactive muscles or other organs such as the liver. (32) In this study, lactic acid buildup significantly increased when subjects engaged in high-intensity exercise on a cycle ergometer. Further examination of the recovery processes reveals that the rates of lactate clearance for AR and PR at the 10-minute mark were equivalent, however AR performs significantly better than PR at the 20-minute mark and UET performs significantly better than both AR and PR at the 10 minute and 20 minute mark. (figure 1;B) Few to no studies have examined low-intensity underwater exercise as a recovery technique but other studies which use active recovery, (33) compression garments (34) or water immersion, (35) (36) techniques which uses similar physiological mechanism as UET for lactate removal produced similar findings.

A recent study by Nam- IK Kim et al. (19) on the impact of deep-sea thalassotherapy on fatigue recovery assesses the advantages of low intensity exercise underwater and reveals that water exercise or deep-sea thalassotherapy can speed up the rate of lactate clearance. However, another similar study (37) which use active recovery exercises underwater for better lactate removal rate disapprove the combined benefits of water immersion and AR on fatigue recovery, this may be because the latter study did not use any physiological measures for load management and fatigue assessment, and because different subjects underwent various recovery techniques, which might have an impact on the findings.

CONCLUSION

The findings of this study suggest that low-intensity underwater exercise is an effective technique for recovering from exercise-induced fatigue. UET involves low-intensity body weight exercise with immersion in water at the same time. Hydrostatic pressure causes venous blood return to increase, raised heart rate causes blood to circulate more rapidly, and more blood gets to the muscles that are being worked out. Faster lactic acid recovery and fatigue recovery were both aided by increased blood circulation. Using UET for the recovery process is simpler than using other advanced recovery modalities; anyone can use it in a pool with a standard depth, also it is simple to supervise.

Future research in this area would be particularly intriguing if they focus on the relationship between body submersion depth, water temperature, and the speed at which underwater training can assist muscles recover from fatigue.

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