CHAPTER II
REVIEW OF RELATED LITERATURE

Introduction

Differing exercise modalities may have unique effects on exercise response variables eliciting different physiological and metabolic responses. The common physiological responses that are used to evaluate effort during maximal and sub-maximal exercise are maximum oxygen consumption, Heart rate, respiratory exchange ratio and Blood lactate. The classical concept of lactate metabolism during exercise suggests that a deficit in oxygen uptake and delivery result in muscle anaerobiosis.

Normally there is a low concentration of lactate in muscle and blood at rest—approximately 1m.Mol./kg wet muscle or litre of blood. The source of this lactate is probably the low resting metabolic rate of muscle that occurs with a low blood flow and the fact that erythrocytes have a low and constant metabolism, the metabolic end product which is lactate.

At low exercise intensities (below about 40% of the VO$_2$max) there may be little or no charge in lactate concentration. As exercise intensity increases, a point is reached at which an increase in the concentration of lactate in the muscle and become evident. The intensity of exercise that
elicits the rise in lactate concentration in muscle and blood is highly variable and is highly influenced by numerous factors.

Keiji (2008) studied to verify whether vHRmax.pred (a running speed corresponding to a HRmax predicted by the formula [220-age (yrs)] was a useful index of endurance performance. vHRmax.pred was compared with V^\^\_O\_2max, vV^\^\_o\_2max (maximal aerobic running speed). vOBLA (running speed at a blood lactate level of 4nmol. L^<-1>) and running speed at exhaustion in 20 male master runners (46-70 yrs), twelve young male runners (21-31 yrs) and 25 junior male runners (12-18 yrs). Methods: Physiological responses (V^\^\_o\_2, HR and LT) were measured during progressive sub-maximal and maximal treadmill running. Running speeds corresponding to HRmax.pred, V^\^\_o\_2max and OBLA were estimated from regression relating the individual's running speed to V^\^\_o\_2, HR, and LA, respectively. Results: A statistically significant correlation (p<0.05) was admitted between vHRmax.pred and V^\^\_o\_2max, vV^\^\_o\_2max, vOBLA, RVE (running speed at the exhaustion or termination point) for the three groups and all participants, except between vHRmax.pred and relative V^\^\_o\_2max for young runners, and relative V^\^\_o\_2max AND vOBLA for junior runners. Conclusion: It was suggested that vHRmax.pred was a potential index of endurance performance regardless of age.
Denandi et al., (2007) analysed the effects of prolonged continuous running performed at the intensity corresponding to the onset of blood lactate accumulation (OBLA), on the peak torque of the knee extensors, analysed in relation to different type of contraction and movement velocities in active individuals. Method: Eight men (23.4 ± 2.1 years; 75.8 ± 8.7 kg; 171.1 ± 4.5 cm) participated in this study. First, the subjects performed an incremental test until volitional exhaustion to determine the velocity corresponding to OBLA. Then, the subjects returned to the laboratory on two occasions, separated by at least seven days, to perform five maximal isokinetic contractions of the knee extensors at two angular velocities (60 and 180°. s-1) under eccentric and concentric conditions. Eccentric peak torque (EPT) and concentric peak torque (CPT) were measured at each velocity. One session was performed after a standardised warm-up period (5 min at 50% VO2 max). The other session was performed after continuous running at OBLA until volitional exhaustion. These sessions were conducted in random order.

There was a significant reduction in CPT only at 60°. s-1 (259.0 ± 46.4 and 244.0 ± 41.4 N.m). However, the reduction in EPT was significant at 60° s-1 (337.3 ± 43.2 and 321.7 ± 60.0 N.m) and 180° s-1 (346.1 ± 38.0 and 319.7 ± 43.6 N.m). The relative strength losses after the running exercise were significant different between contraction type only at 180° s-1. The results concluded that, in active individuals, the reduction in peak torque after
prolonged continuous running at OBLA may be dependent on the type of
contraction and angular velocity.

Hirvonen studied fatigue during the 400 metre sprint by measuring
muscle ATP, creatine Phosphate (CP), muscle lactate (M – la), and blood
lactate (M – La) in six male runners before and after four experimental sprints
(200, 200, 300 and 400 metres). During the first 100m, muscle CP decreased
from 15.8 ± 1.78 to 8.3 ± 0.3 n. mol./Kg. while M – la increased from to 3.6 ±
0.4 m.mol. / Kg. After 200m. the CP had decreased to 6.5 ± 0.5 m. mol./Kg
and M – la had increased to 8.3 ± 1.1 m. mol. / Kg. At the end of the 400
metres, ATP and CP concentrations had decreased by 27% and 89%
respectively, and M – la had increased to 17.3 ± 0.9 m. mol. / Kg.

Bouhlel et al., (2006), studied heart rate and blood lactate responses
during Taekwondo training and competition. The study investigated physical
fitness characteristics of elite Taekwondo (TKD) players as well as their heart
rate (HR) response and blood lactate concentration changes during TKD
specific exercises and simulated competition.

Anaerobic and aerobic power has been evaluated in eight elite TKD
players (age: 20 ± 1 years, body mass: 70.8 ± 6 kg, Ht: 179.9 ± 4 cm). Heart
rate and blood lactate concentration were measured during competition and
specific-exercises (front kicks during 10s, 1 and 3 min). Maximum oxygen
uptake (VO₂ max) and peak anaerobic power (Wpeak) average 56.22 ± 2.57
ml min\(^{-1}\) kg\(^{-1}\) and 12.1 \(\pm\) 1.7 W kg\(^{-1}\), respectively. HR and blood lactate [La] concentrations increased significantly during competition \(F = 19.4, P < 0.001; F = 21.3, P < 0.001\) compared to the resting value. HR and [La] values were significantly correlated with those measured during 10s \((R = 0.85, P < 0.05 \text{ and } R = 0.79, P < 0.05\). TKD requires high levels of both aerobic and anaerobic physical fitness. The correlation between specific exercises and competition is of practical interest for TKD players and trainers.

Ghosh, Goswami and Ahuja (October 1995) investigated heart rate and blood lactate response on twenty six senior national level boxers in competitive bouts to explore the anaerobic – aerobic metabolism as well as the training status of the players.

Heart rate and blood lactate concentration were measured during warm up and boxing rounds. No interweight category as well as inter round difference were observed in the heart rate and blood lactate concentration of the boxers excepting in the forty eight and fifty seven kilogram categories, the mean blood lactate levels in the second and third rounds were higher than the first round. When all the weight categories were pooled, the mean heart rate and blood lactate levels were 178 beats/minute and 8.24 m.mol/ltr respectively. The study highlights than in amateur boxing, irrespective of weight category and aerobic capacity, the anaerobic capacity of the boxers were the same. The training requirements of the boxers demand that they
should be able to tolerate a high blood lactate level (approximately 9.0 m.mol./ltr.) and a high heart rate (approximately 180 beats/minute) over a total duration of one bout.

Larson (2006) studied heart rate at blood lactate threshold due to exercise mode in elite cross-country skiers. This study attempted to quantify the difference in heart rate and exercise stage at which blood lactate threshold (Tbla) occurs using 3 different modes of exercise: running, double poling (DP) on roller skis, and skating (SK) on roller skis. Nine elite collegiate cross-country ski racers (4 men, 5 women) served as test subjects. Testing was conducted on a motorized FitNex treadmill, specially designed for roller skiing. Heart rate was monitored via telemetry with values averaged over the last 30 seconds of each stage. A 40-μl blood sample was obtained at the fingertip at the end of each 4-minute stage, and 25μl was analysed for whole blood lactate concentration. The Tbla was determined by the first exercise state that elicited a concentration over 4.0 nmol.L⁻¹. The same test protocol was used for all 3 exercise modes. Mean heart rate, in beat per minute (b.min⁻¹), at Tbla was not significantly different (P > 0.05) for SK (mean 187 ± 14 b.min⁻¹ SD) vs. running (mean 187 ± 12.b.min?SD); however, heart rate was significantly lower at Tbla for DP (mean 161 ± 17 b.min⁻¹ SD) vs. running and DP vs. SK. The mean exercise protocol stage that induced a blood lactate value which exceeded Tbla was significantly different (P > 0.05)
for running (5.22 ± 1.20 n.mol.L⁻¹ SD) vs. DP (1.89 ± 0.78 n.mol.L⁻¹ SD),
running vs. SK (3.67 ± 0.71 mmol.L⁻¹ SD), and SK vs. DP.

It was concluded that Tbla occurs at a lower heart rate and exercise
stage during DP as compared with SK on running. Therefore, it stands to
reason that the heart rate at Tbla may vary based on mode of exercise, and
when using heart rate to estimate blood lactate concentration, coaches and
athletes should be aware that different modes of exercise elicit a different
blood lactate concentration at a given heart rate depending on exercise mode
used.

Rebiero et al., (2006) studied the effect of blood lactate and heart rate
responses in combat sports. The development of specific training designed to
enhance physiological aspects of performance relies heavily on the
availability of accurate and validity physiological data. In the combat sport of
Wushu, katas are used to develop aerobic fitness. It is arguably important to
assess and monitor heart rate (HR) and lactate (La) responses when designing
effective training programs. The aim of this pilot study was to investigate
heart rate and lactate responses to forms execution among Wushu combatants.
Male elite modern Wushu athletes (n = 4) from a South Brazilian regional team
participated in the study. Athletes were aged 22.5 ± 2.08 years old and had at
least eight years of Wushu experience. Athletes carried out the Changquan
and Daoshu forms in random order, HR and La were measured pre and post
exercise. Results indicate that HR was 176 ± 3 and 176 ± 2 bpm and La was 4.38 ± 1.3 and 5.15 ± 1.07 m mol.l−1 for Changquan and Daoshu forms, respectively.

There were no significantly differences in HR and La between the two forms. HR values represent 89.2 ± 1.1 and 89.1 ± 1.8% of age-predicted maximal heart rate and lactate was near of 4 m mol.l−1 point. In conclusion, training programs to Wushu combatants could target the range of physiological values cited above with no differences between two forms.

Koch and Raschka (2005) in their study, exposed nineteen healthy volunteers to a standardized exercise test at sea level (Sla), at an altitude of 1700 m before (1700a) and after a moderate 10-day mountain training (1700b), with a final control four weeks later at sea level (SLb). Vital signs, blood lactate and arterial oxygen saturation were determined prior, during or after the exercise test. Whereas systolic blood pressure and heart rate at rest did not change substantially, diastolic blood pressure decreased at the final control (SLb, p<0.05) and oxygen saturation was significantly lower at 1700 m (1700a, 1700b, p<0.01). Lactate at rest increased from 1.16 (Sla) to 1.97 (1700a) nmol/l after acute exposure followed by a slight reduction after adaptation (p<0.05). The mean maximum lactate levels were as follows: 6.03, 10.56, 6.22 and 8.75 (p<0.01). The mean maximum performance increased during the study (225.6, 223.3, 231.6, 248.1 Watt, p<0.01). Lactate versus
workload curves did not show a marked shift to the right. No significant changes of maximum heart rates during the exercise test were found. In conclusion, a sojourn at 1700 m provokes an increase of lactate levels with subsequent reduction after acclimatisation and has a significant positive impact on the mean maximum performance after moderate mountain training.

Billat (2004) investigated training effects on time-to-exhaustion, substrate and blood lactate balances at the maximal lactate steady state velocity (MLSSv) were examined. Even male, veteran, long-distance runners performed three tests before and after 6 weeks of training at MLSSv: an incremental test to determine maximum O\textsubscript{2} uptake (VO\textsubscript{2} max) and the velocity at the lactate threshold (vLT), a sub-maximal test of two stages of 20 min. at 95 and 105% of vLT separated by 40 min rest to determine the MLSSv and the corresponding lactate concentration (MLSSc) and a time-to-exhaustion run at MLSSv for which the substrate balance was calculated. Duration and distance run at MLSSv increased dramatically respectively from 44 ± 10 to 63 ± 12 min and from 10.4 to 15.7 km respectively (P<0.01). MLSSv increased significantly with training but the relative fraction of VO\textsubscript{2} max remained the same (85.2 ± 4.5 vs. 85.3 ± 5.2%, P = 0.93). MLSSc was unaffected by training as determined from the percentage of energy yielded by carbohydrates (80%) during the exhaustive run at MLSSv.
These findings show that training at MLSS elicits small increases in MLSSv and VO\textsubscript{2} max, but enhances time-to-exhaustion (endurance) at MLSSv substantially (+50%). Training does not change the proportion of carbohydrate oxidized, which is the major substrate used during an exhaustive run at MLSS lasting 1h.

Daisuke et al., (2004) studied to examine the effects of various rest periods during intermittent exercise with respect to blood lactate concentrations in Thoroughbred horses. Four Thoroughbred horses each underwent three types of intermittent exercise program and blood lactate concentrations during the exercise, which was carried out on a 7% inclined treadmill, were measured. The intensity of each bout was set at 116% HRmax for 50 sec. Each program comprised three bouts separated by rest periods set at either 2, 5 or 15 min. Blood lactate concentrations during the second and third bouts increased approximately 6 mmol/l in the 15 min intermittent exercise program, but almost no changes were observed during all bouts in the 5-min intermittent exercise program. By contrast, blood lactate concentrations decreased during bouts in the 2-min intermittent exercise program. It is considered that this suggests more lactate in muscles was oxidised to supply energy in the 2-min intermittent exercise program than in the other two exercise programs. It is therefore the responses. Finally, the investigation demonstrated no significant difference in lactic acid responses among the three recovery conditions.
Katayama et al., (2003) studied to elucidate the influence of intermittent hypobaric hypoxia at rest on endurance performance and cardio-respiratory and haematological adaptations in trained endurance athletes. Twelve trained male endurance runners were assigned to either a hypoxic group (n = 6) or a control group (n = 6). The subjects in the hypoxic group were exposed to a simulated altitude of 4500 m for 90 min, three times a week for 3 weeks. The measurements of 300 m running time, running time to exhaustion, and cardio-respiratory parameters during maximal exercise test and resting haematological status were performed before (Pre) and after 3 weeks of intermittent hypoxic exposure (Post). These measurements were repeated after the cessation of intermittent hypoxia for 3 weeks (Re). In the control group, the same parameters were determined at Pre, Post, and Re for the subjects not exposed to intermittent hypoxia. The athletes in both groups continued their normal trained together at sea level throughout the experiment. In the hypoxic group, the 3000 m running time and running time to exhaustion during maximal exercise test improved. Neither cardio respiratory parameters to maximal exercise nor resting haematological parameter were changed in either group at Post, whereas oxygen uptake (VO₂) during sub-maximal exercise decreased significantly in the hypoxic group. After cessation of intermittent hypoxia for 3 weeks, the improved 3000 m running time and running time to exhaustion tended to decline, and the decreased VO₂ during sub-maximal exercise returned to Pre level.
These results suggest that intermittent hypoxia at rest could improve endurance athletes, but these improvements are not maintained after the cessation of intermittent hypoxia for 3 weeks.

Ozcelik and Kelestimur (2004) investigated the validity of non-invasive lactate threshold estimation using ventilator and pulmonary gas exchange indices under condition of acute hypoxia. Seven untrained males (21.4 ± 1.2 years) performed two incremental exercise tests using an electromagnetically braked cycle ergometer: one breathing room air and other breathing 12% O₂. The lactate threshold was estimated using the following parameters: increase of ventilator equivalent for O₂ (VE/VO₂) without increase of ventilator equivalent for CO₂ (VE/VCO₂). It was also determined from the increase in blood lactate and decrease in standard bicarbonate. The VE/VO₂ and lactate increase methods yielded the respective values for lactate threshold: 1.91 ± 0.10 l/min (for the VE/VO₂) vs. 1.89 ± 0.1 l/min (for the lactate). However, in hypoxic condition, VE/VO₂ started to increase prior to the actual threshold as determined from blood lactate response: i.e. resulted in pseudo-threshold behaviour. In conclusion, the ventilator and gas exchange indices provide an accurate lactate threshold. Although the potential for pseudo-threshold behaviour of the standard ventilator and gas exchange indices of the lactate threshold must be concerned if an incremental test in
performed under hypoxic conditions in which carotid body chemosensitivity is increased.

Moura et al., (2002) studied the effects of exercise and water replacement on intraocular pressure (IOP) have not been well established. Furthermore, it is not known whether the temperature of the fluid ingested influences the IOP response. In the present study we determined the effect of water ingestion at three temperatures (10, 24, 38°C; 600 ml 15 min before and 240 ml 15, 30 and 45 min after the beginning of each experimental session) on the IOP of six healthy male volunteers (age = 24.0 ± 3.5 years, weight = 67.0 ± 4.8 kg, peak oxygen uptake (VO₂ peak) = 47.8 ± 9.1 ml kg⁻¹ min⁻¹).

The subjects exercised until exhaustion on a cycle ergometer at a 60% VO₂ peak in a thermo neutral environment. IOP was measured before and after exercise and during recovery (15, 30 and 45 min) using the applanation tonometry method. Skin and rectal temperatures, heart rate and oxygen uptake were measured continuously. IOP was similar for the right eye and the left eye and increased post water digestion under both exercising and resting conditions (P<0.05) but did not differ between resting and exercising situations, or between the three water temperatures. Time to exhaustion was not affected by the different water temperatures. Rectal temperature, hydration status, heart rate, oxygen uptake, carbon dioxide extraction and lactate concentration were increased by exercise but were not affected by
water temperature. We conclude that IOP was not affected by exercise and that water ingestion increased IOP as expected, regardless of water temperature.

Willmert et al., (2002) studied the effect of oxygenated water on exercise physiology during incremental exercise and recovery. The breathing of supplemental study was to investigate whether results from lactate threshold tests on a treadmill would be influenced by collecting blood during thirty second intervals (intermittent) as compared to sampling during continuous running.

Ten well-trained middle and long-distance runners ran the two protocols randomly on separate days with the same speed both times. Values of blood lactate, heart rate and ratings of perceived exertion (RPE) were compared. The results showed no significant difference in and of the variables compared the two regiments. It was concluded that for well trained middle and long distance runners, any of the two regimes can do chosen without affecting the threshold results.

Rodriguez-Alonso et al., (2003) studied Blood lactate and Heart rate during national and international women's basketball players. In order to measure game intensity in female basketball players, 2 teams (Olympic National Team – I – and a team at 1st National Division – N) were studied for a total of 12 games (10 official competitions and 2 practice games – P).
Both Blood lactate concentration ([La]b) and mean Heart rate (HR) were measured during the games and then compared with a progressive field test where maximal blood lactate (max[La]b), individual lactate threshold and maximal heart rate (HR max) values were obtained. All different categories (International, National and Practice) and positions (Guard, Forward and Centre) were taken into account in this study.

Result: Differences (p<0.05) in HR were found between all positions (Guard = 185 ± 5.9; Forward = 175 ± 11 and Centre = 167 ± 12 beats min-1) and between the International team and the rest of the categories (International = 186 ± 6; National = 175 ± 13 and Practice = 170 ± 11 beats min-1). The [La]b differed between the Guard and the other 2 positions (Guard = 5.7 ± 2.1; Forward = 4.2 ± 2.1 and Centre = 3.9 ± 2.0 nmol L-1) and between Practice and the rest of the categories (International = 5.0 ± 2.3; National = 5.2 ± 2.0 and Practice = 2.7 ± 1.2 nmol L-1). The game intensity of International players reached 94.6% of their maximum HR value, whereas National players reached 90.8%, this percentage descending to 89.8% during Practice. International games reached the individual lactate threshold at 89.2% of the maximum HR; National games at 88.6%.

The study concluded that the game intensity of female basketball increases according to the level of competition. It may also differ according to playing position, being greatest in guards. The game intensity at international
level surpasses the individual lactate threshold, whereas it reaches a lower level in training games.

Ghosh et al., (1990) investigated heart rate and blood lactate response in competitive badminton. Ten junior level (13-14 years of age) female badminton players were studied to investigate the demands of the game on heart rate and blood lactate during competition. The VO$_2$ max and anaerobic threshold level were 48.3 ml/kg/min. and 66.3% of the VO$_2$ max. Game analysis revealed that heart rates were higher in the second and third games than in the first game, whereas no difference was found in the blood lactate concentration. Anaerobic threshold heart rate and total duration of the game indicated an anaerobic – aerobic time domain ratio of 3:1. The authors concluded that junior national level female badminton players attained optimum aerobic capacity and anaerobic threshold levels that could be improved later through further training and dissimilar strain on the cardiovascular and anaerobic metabolic system is possible due to the intermittent nature of the game.

De Angelis (1998) investigated the physiological responses and in particular, the participation of lactic acid anaerobic metabolism in aerobic dance, which is claimed to be pure aerobic exercise. In contrast to previous studies, that have put subjects in very unfamiliar situations, the parameters
were monitored in the familiar context of gymnasium, practice routine and habitual instructor.

A group of 30 skilled fairly well-trained women performed their usual routine, a combination of the two styles; low (LI) and high impact (HI), and were continuously monitored for heart rate (HR) and every 8 min for blood lactate concentration ([La-]b). Of the group, 15 were tested to determine their maximal aerobic power (VO\textsubscript{2}\text{max}) using a cycle-ergometer. They were also monitored during the routine for oxygen uptake (VO\textsubscript{2}) by a light telemetric apparatus. The oxygen pulses of the routine and of the corresponding exercise intensity in the incremental test were not statistically different. The mean values in the exercise session were: peak HR 92.8 (SD 7.8)% of the subject's maximal theoretical value, peak VO\textsubscript{2} 99.5 (SD 12.4)% of VO\textsubscript{2}\text{max}, maximal [La-]b 6.1 (SD 1.7) nmol x 1(-1), and mean 4.8 (SD 1.3) nmol x 1(-1). Repeated measures ANOVA found statistically significant differences between the increasing [La-]b values (P<0.001). In particular, the difference between the [La-]b values at the end of the mainly LI phase and those of the LI-HI combination phase, and the difference between the samples during the combination LI-HI phase were both statistically significant (both P = 0.002 and P = 0.002). The similar oxygen pulses confirmed the validity of the present experiment design and the reliability of HR monitoring in this activity. The HR, VO\textsubscript{2} and, above all, the increase of [La-]b to quite high values, showing a non-steady state, demonstrated the high metabolic demand
made by this activity that involves lactic acid metabolism at a much higher level than expected.

Mygind, Anderson and Rasmussen (1994) investigated blood lactate and respiratory variables in the cross-country skiing at racing speeds. The relative mean oxygen uptake for classical skiing was 88% for level and 93% for uphill terrain. The respective means for skating 91% for level and 91% for uphill terrain. The mean value and range for blood lactate at race speeds were 10.6 m.M. and 9.2 m.M. for skating and classical respectively. A relatively study state was achieved after the first lap, although a slight but significant blood lactate accumulation took place until finish. The respiratory exchange ratio in both skiing styles varied between 0.88 – 0.90 and 0.92 – 0.93 for flat and up hill terrain respectively, indicating a large lipid oxidation at these very high exercise intensities.

Jefry Aron Potteiger (1991) examined the psychological responses which occur during an acute bout of baseball pitching on six male college baseball players pitching in a simulated game. Heart rate, lactate, serum glucose, free fatty acid and oxygen consumption were measured during the pitching performance. Heart rate exhibited a quadratic effect. There was no change from pre exercise values for lactate or serum glucose. Free fatty acid increased significantly throughout the game. VO₂ exhibited a quadratic effect during each inning with maximal values reaching 20.6 ml./Kg/Minute. The
results indicated that the physiological responses which occur during the pitching of a game corresponds to an intensity equal to continuous exercise at 45% of the VO\(_2\) max.

Tetsyo Ohkuwa and Loth (1992) examined blood lactate, glycerol and catecholamine in the venous blood in eight recreational swimmers following sixty seconds of supra-maximal arm strokes, kicks and the whole swim. The mean velocity of the whole stroke was higher than both arm strokes and kicks, and the mean velocity of arm strokes were higher when compared with kicks. Peak blood lactate in the whole swim was higher than arm strokes and kicks, and peak blood lactate in arm strokes was higher compared to kicks. The correlation coefficient between mean velocity and peak blood lactate in arm strokes, leg kicks and whole swim were \(r = 0.72\); \(r = 0.61\) and \(r = 0.35\) respectively. The result suggested that lactate in the blood during crawl stroke originates predominantly from the muscle groups which work the arm, and that glycogen included in the muscles of the upper body which is use during arm swim, while additional energy from the leg muscles is not fully sufficient to increase propulsion force in a linear manner.

Meir, Lowdon and Davie examined heart rates and subsequent estimated energy expenditure during one hour of recreational surfing. Six male volunteers, age 21.2 ± 2.7 years, participated in the study. Mean heart rate while recreational surfing was 135 ± 6.9 beats / Minutes and 127 ± 6.9
beats / minute respectively. Mean heart rates for the total time surfing, padding and stationary represented 75%, 80% and 71% respectively of the group's mean peak heart rate attained in the laboratory. Mean total time spent in stationary, padding and riding waves represented 35%, 44% and 5% of the total time surfing respectively.

Wasserman, Connolly and Pagliassotti (1991) reports on the regulation of hepatic lactate balance during exercise. The rate of change of lactate across the liver gives important insights into intracellular process during muscular work. At the on set of exercise, hepatic glycogenolysis increase rapidly, resulting in high rates of glycolytic flux and a transient rise in lactate output. With increasing exercise duration, gluconeogenesis is accelerated and the liver gradually shifts from a lactate – producing to a lactate – consuming state. Exercise induced changes in hormone levels are critical in the regulation of hepatic glycogenolysis and gluconeogenesis and therefore, net hepatic lactate balance.

Hurley et al., (1984) studied effects of blood lactate during submaximal exercise. Eight men were studied before and after a 12-wk exercise program to determine the effect of training on blood lactate levels during submaximal exercise. The training elicited a 26% increase in maximum O₂ uptake (VO₂ max). Lactate concentrations at the same relative exercise intensities in the 55-75% of VO₂ max range were significantly lower after
training. A significantly higher relative exercise intensity was needed to elicit a given level in the 1.5 to 3.0 mM range after training. O₂ uptake at the work rate required to raise blood lactate 2.5 mM was 39% higher after training. A blood lactate 2.5 mM was attained at 68 ± 4% VO₂max before and 75±3% of VO₂max after training. Eight competitive runners required an even higher relative work rate (83 ± 2% of VO₂max) to attain a blood lactate of 2.5 mM.

These data provide evidence that the adaptations to training that result in an increase in VO₂ max are, to some degree, independent of those responsible for the lower blood lactate levels during sub-maximal exercise.

Goswami, Mathur and Ghosh (1995) investigated blood lactate removal pattern after sub-maximal and supra-maximal exercises. The purpose of the study was to focus on possible differences in the recovery lactate kinetics after sub-maximal and maximal exercise in the case of ten sports persons. Investigation of lactate kinetics was done in two phases. In phase one, the subjects were administered with sub-maximal exercise at 50% of VO₂ max on the treadmill for five minutes. The blood samples were collected at the end of the exercise and at 3, 10, 20, 30, 40 and 60 minutes of recovery. In phase two, supra-maximal exercise at 150% of VO₂ max. until exhaustion was administered on the same subjects on another day. Analysis of the results revealed that the nature of recovery in both the cases was similar but the half life of lactate had significant differences. The study concludes
that removal of blood lactate is possibly dependent on the degree of its accumulation in the blood.

Gullstrand, Sjodin and Svedenhag (1994) conducted a study on blood sampling during continuous running and thirty second intervals on a treadmill. The aim of the oxygen has been used as a potential ergogenic aid for many years. Recently, consumption of water that is purported to contain 7 – 10 times the normal amount of oxygen ("super oxygenated" water) has been marked with claims that it can enhance both exercise. The purpose of this study was to refute/substantiate those claims. Twelve college-aged volunteers (6 male, 6 female) completed two, sequential maximal exercise tests using a modified Bruce protocol, on two separate days. Fifteen minutes before exercise, subjects' randomly consumed 500 mL of either super oxygenated water or bottled water. Variables measured included resting, sub-maximal, and maximal heart rate, blood pressure, ratings of perceived exertion, and blood lactate.

There were no significant differences between conditions for any of the variables at rest or during exercise. Data collected during the second test in the sequence were done to assess recovery.; There were no differences between conditions for any of the variables measured during this test. The results suggest that the consumption of oxygenated water has no effect on incremental exercise to VO$_2$max or on recovery from strenuous exercise.
Redondo (1991) compared cardiovascular and lactic acid (LA) responses during three recovery positions following maximal exercise on the treadmill. Ten male subjects were tested using a non-invasive CO$_2$ re-breathing technique to measure cardiac output (Q). Finger sticks were also performed to obtained whole blood samples for LA analysis. The analysis revealed that when compared to sitting and supine recovering resulted in similar responses, but different means of achieving suggested that a 2-min intermittent exercise program more effectively stimulates the lactate oxidation system in Thoroughbred horses than do programs with longer rest periods.

Marciniak E.J. et al., (1991) conducted a study to determine the effects of twelve weeks strength training on lactate threshold and endurance performance. Eighteen healthy untrained males between twenty five and thirty four years of age were randomly assigned to either strength training (N = 10) or control (N = 8) groups. Findings indicated that strength training improved cycle endurance performance independently of changes in VO$_2$ max. This improved performance appears to be related to increase in lactate threshold and leg strength.

Oayashi and Yagi (1991) studied heart rate responses relating to 25m, 50m and 100m in twenty boys and twenty girls of six years old. The subjects were chosen from 120 children of the same age groups as ten good runners.
(Group A) and ten poor runners (Group B) for boys and girls respectively. Heart rates were recorded using the telemetry system before and during running, and three minutes recovery period. It was concluded that higher level of heart rate would be observed for children who show higher performance in short distance running. As for the case of long distance running, it was probably that children having high running ability were adapted to high intensity exercise with higher level if cardiovascular responses.

Rumley et al., (1988) studied the effect of marathon training on the plasma lactate response to sub-maximal exercise in middle-aged men. Twenty-one previously sedentary male volunteers (aged 35-50 years) undertook a defined marathon training programme lasting 30 weeks. At weeks 0 (T1), 15 (T2) and 30 (T3) they underwent measurement of maximal oxygen uptake (VO2 max), sub-maximal VO2 and sub-maximal plasma lactate concentration during cycle ergometry. No exercise was taken for 24-48 hours prior to testing. During training aerobic power increased significantly (p less than 0.001) from an initial VO2 max at T1 of 33.9 ± 6 (mean ± sd) ml.kg-1min-1 to 39 ± 5.6 ml.kg-1min-1 at T2 but the T3 value of 39.2 ± 5.2 ml.kg-1 min-1 was not significantly different from that at T2. Plasma lactate concentration of 4 mmol.l-1 (OBLA_w) occurred at a significantly (P less than 0.05) higher workload (155 ± 28 w) at T2 comared with T1 (132 ± 30w) but the T3 figure was 137 ± 34w. OBLA VO2 at T1 was 2.04 ± 0.42 1.min-1, at T2 was 2.24 ± 0.04 1. Min-1 but at T3 was 2.03 ±
0.30 l.min\(^{-1}\) (T1:T2 \(P < 0.05\), T1:T3 \(P \text{ NS}\)). OBLA \% VO\(_2\) max at T1 was 75 ± 12\%, at T2 was 73 ± 11\% but at T3 was 62 ± 10\% (T1:T2 \(P \text{ NS}\), T1:T3 \(P < 0.01\)).

Dodd et al., (1984) studied blood lactate disappearance at various intensities of recovery exercise. Numerous studies have reported that following intense exercise the rate of blood lactate (La) disappearance is greater during continuous aerobic work than during passive recovery. Recent work indicates that a combination of high and low intensity work may be optimal in reducing blood La. We tested this hypothesis by measuring the changes in blood La levels following maximal exercise during four different recovery patterns. Immediately following 50 S of maximal work, subjects (n = 7) performed one of the following recovery treatments for 40 min: 1) passive recovery (PR); 2) cycling at 35\% maximal O2 uptake (VO\(_2\) max) (35\% R); 3) cycling at 65\% VO\(_2\) max (65\% R); 4) cycling at 65\% for 7 min followed by cycling at 35\% for 33 min. (CR). The treatment order was counterbalanced with each subject performing all treatments. Serial blood samples were obtained throughout recovery treatments and analysed for La. The rate of blood La disappearance was significantly greater (\(P < 0.05\)) in both the 35\% R and CR when compared with either the 65\% R or PR. No significant difference (\(P > 0.05\)) existed in the rate of blood La disappearance between the 35\% R and CR. These data do not support the hypothesis that exercise recovery at a combination of intensities is superior to a recovery involving continuous sub-maximal exercise in lowering blood La following maximal work.