Chapter 2
Review of Related Literature
Chapter-II
REVIEW OF RELATED LITERATURE

The review of related literature provides us guidelines in pursuing the study along with knowing the significance of our study in relevance to studies undertaken by other scientist. The studies of specific as well as peripheral relevance to this study are cited below.

Diana Rimaud; Laurent Messonnier; Josiane Castells; Xavier Devillard; Paul Calmels (2010), conducted a study to investigate if wearing compression stockings (CS) during exercise and recovery could affect lactate profile in sportsmen. Eight young healthy trained male subjects performed two maximal exercise tests on a cycle ergometer on two different occasions performed randomly: CS during both exercise and recovery, and no CS. Blood lactate concentration was taken during exercise and at 0, 3, 5, 10, 15, 30 and 60 min post-exercise. The individual blood lactate recovery curves were fitted to a biexponential time function: [Formula: see text], where gamma (1) and gamma (2) denote the abilities to exchange lactate between the previously active muscles and the blood and to remove lactate from the organism, respectively. A significantly higher blood lactate value at the end of the maximal exercise was found (12.1 +/- 0.5 vs. 10.8 +/- 0.5 mmol l(-1)) wearing CS as compared to no CS (P < 0.05). Lower gamma (1) and higher gamma (2) values were observed with CS during recovery, as compared to no CS. It was concluded that CS during graded exercise leads to a significant higher blood lactate value at exhaustion. Since
lactate exchanges were expected to be decreased during exercise due to CS, this result was likely attributable to a higher lactate accumulation related to a greater overall contribution of anaerobic glycolysis. Although the lactate removal ability was significantly improved when wearing CS during recovery, its efficacy in promoting blood lactate clearance after high-intensity exercise is limited

**Bellezza PA, Hall EE, Miller PC, and Bixby WR. (2009)** examined the influence of exercise order on blood lactate, perceptual, and affective responses to resistance exercise. Twenty-nine subjects (18 women, 11 men; 20.9 ± 1.9 years) completed three sessions separated by a minimum of 48 hours. Session 1 determined the 10-repetition maximum (10RM) for nine resistance exercises. During sessions 2 and 3, exercises were completed in either a large to small or small to large muscle exercise order. The large to small muscle order was 1) chest press, 2) leg press, 3) rows, 4) leg extension, 5) overhead press, 6) hamstring curl, 7) biceps curl, 8) calve raise, and 9) triceps extension. Exercise order was reversed for the small to large condition. Participants performed two sets of each lift, with the first set being a warm-up at 80% 10RM, followed by one set at 100% 10RM with 1 minute of rest between each exercise. Rating of perceived exertion (RPE) was measured after completion of the second set. Blood lactate was recorded after exercises 1, 5, and 9. Affective measures were completed pre, during, post 0, and post 10 minutes. Lactate showed a significant time ($p < 0.001$) and condition × time interaction ($p = 0.020$). A significant difference was seen in average
number of repetitions completed between sequences, with small to large performing more. There were no differences seen between exercise orders for average RPE. Analyses of Feeling Scale and Felt Arousal Scale scores showed only a significant main effect of time. A paired-sample t-test was conducted to examine differences in Feeling Scale for the two conditions at the different time points. Significant differences were found for Feeling Scale during exercise (after overhead press) and at post 10, with the small to large exercise order having greater Feeling Scale responses. No significant correlations were seen between blood lactate and perceptual or affective responses at any time point or in either exercise order. These findings may suggest that small to large exercise order may have beneficial physiological and psychological outcomes and potentially influence exercise adherence.

Kaur Rajpreet, Kumar Rajendra, and Sandhu Jaspal (2008) evaluated the effects of various warm-up protocols on endurance, blood lactate concentration and VO_{2}\text{max}. 15 healthy male participants were randomly exposed to each of three different warm up protocols with a 2 days' gap in between in a random sequence. Each warm up protocol was preceded by 5 min of jogging, that is, Protocol I (P-I): Static stretching, Protocol II (PII): Moderate to high intensity dynamic exercises, Protocol III (PIII): Dynamic stretching and Control group: only jogging. It was preceded and followed by determination of blood lactate concentration (P-LM5 Analyser), VO_{2}\text{max} and treadmill performance test at 65% to 75% heart rate reserve. Results showed a more significant decrease in
blood lactate concentration after PII (t=16.91) than > PIII (t=11.72) and > PI (t=12.45); p < 0.001, also there was more significant increase in VO$_2$max with PII (t=10.82) than > PIII (t=5.11) and > PI (t=4.13); p< 0.001. Similar results were observed for treadmill time to exhaustion [PII (t=4.69)> PIII (t=3.27); (p<0.05)> PI (t=1.91)] respectively. It is concluded that dynamic warm up exercises may be a more viable method for enhancing endurance than stretching.

Paharapong Yingedamnum (2007) conducted this study to compare the effects of interval training and weight training on blood lactate level and athletes performances. Twenty male subjects were sports science students of Mahidol University aged 18-22 years. Statistical method of simple random sampling was used in this study subjects were divided into three groups. Control group (n=07), interval (n=07) and weight training group (n=06) both training groups were trained at the same duration (40-50 min) and frequency (3 times/week) for 6 weeks. The intensity of interval training was set at 70% maxHR during high intensity exercise and 50% maxHR during low intensity exercise the intensity of weight training was set at 70% RM using weight machines. Data collected including body fat, lung vital capacity, anaerobic capacity, running time test and blood lactate level (by Bruce’s protocol) before and after each exercise training programme paired t-test and one way ANOVA were used to analyse the data. The level for statistical difference was set at p<0.05.
The result showed that maximum oxygen consumption, leg strength, flexibility, lung vital capacity, anaerobic capacity of the post training in interval training group and weight training group were significantly (p<0.05) higher than the pre-training percent of body fat did not change. It was found that two exercise training programme had influenced on blood lactate level. Interval training programme significantly decreased lactate level in blood capillary more than the weight training programme. This findings suggested that two training programme were beneficial to develop strength, anaerobic power and delay muscle fatigue. Moreover, higher intensity training may improve running time performance in 400 meter distance. A longer exercise training period and higher intensity training in other methods are recommended for further research.

Zeni AI, Hoffman MD, Clifford PS (1996) observed that exercise training intensity for aerobic conditioning is typically established by heart rate (HR), oxygen uptake, or rating of perceived exertion (RPE). Recent research, however, suggests that the optimal training intensity may be more appropriately established from measurements of blood lactate concentration ([LA]). This study examined the relationships among three of these training intensity variables--HR, RPE, and [LA]--for six modes of rhythmic exercise. Ten healthy women subjects underwent a 4-week habituation period to become familiar with the RPE scale and exercise on a treadmill, cycle ergo meter, rowing ergo meter, Air dyne, stair stepper, and cross-country skiing simulator. Following
habituation, each subject underwent graded discontinuation exercise testing on each mode. HR was measured during the last minute of each 4-minute stage. Immediately after each stage, RPE was requested and blood was collected for analysis of [LA]. Data were analyzed with repeated measures ANOVA. For given RPE values, the treadmill induced higher (p < .05) HR values compared with the cycle and rowing ergo meters, and the cycle ergo meter induced lower (p < .05) HR values compared with the treadmill, Air dyne, stair stepper, and cross-country skiing simulator. The relationships of [LA] with RPE were similar among modes except for the cross-country skiing simulator, which induced a lower (p < .05) [LA] for a given RPE. Since the relationships of HR and [LA] with RPE are not the same for all forms of rhythmic exercise that use a large muscle mass, we conclude that mode specificity should be considered when prescribing aerobic exercise.

B. F. Hurley, J. M. Hagberg, W. K. Allen, D. R. Seals, J. C. Young, R. W. Cuddihee and J. O. Holloszy (1984) studied eight men 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 (VO2max). Lactate concentrations at the same relative exercise intensities in the 55-75% of VO2max range were significantly lower after training. A significantly higher relative exercise intensity was needed to elicit a given lactate level in the 1.5- to 3.0-mM range after training. O2 uptake at the work rate required to raise blood lactate to 2.5 mM was 39% higher after training. A
blood lactate of 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 VO2max are, to some degree, independent of those responsible for the lower blood lactate levels during submaximal exercise.

Stegmann H, Kindermann W (1982) conducted a study in which prolonged physical exercise tests (50 min) at the threshold of 4 mmol . l-1 lactate (ATc) and at the individual anaerobic threshold (IAT) were applied in 19 rowing athletes. In each of the rowers (n = 19) work loads corresponding to the IAT did not result in a gradual lactase accumulation or exhaustion within 50 min of exercise. Means of lactate concentration and heart rate at the end of exercise were 4.0 +/- 1.6 mmol . l-1 and 182 +/- 13.0 beats . min-1, respectively. In 15 of 19 rowers, the IAT corresponded to lower work loads than the ATc. In these cases, prolonged exercise tests at the ATc showed gradual increases in lactate concentrations to a mean of 9.6 +/- 1.2 mmol . l-1, associated with exhaustion at a mean working time of 14.4 +/- 6.3 min and a mean heart rate of 192 +/- 10.4 beats . min-1. In four rowers, the IAT was found at identical (n = 3) or higher (n = 1) work loads than the ATc. In these cases, after an initial increase no further rise in lactate concentrations in blood was observed, and exhaustion did not occur during the prolonged exercise.
tests. These findings support the conclusion derived from the lactate kinetics model that the IAT defines the work load at the maximal lactate steady state.

Chwalbińska-Moneta J (2003) investigated the effect of oral creatine supplementation on aerobic and anaerobic performance on 16 elite male rowers during 7-day endurance training. Before and after the daily ingestion of 20 g creatine monohydrate for 5 days (Cr-Group, n=8) or placebo (Pl-Group, n=8), subjects performed two exercise tests on a rowing ergometer: (a) incremental exercise consisting of 3-min stage durations and increased by 50 W until volitional exhaustion; (b) an all-out anaerobic exercise performed against a constant load of 7 W/kg. Heart rate and blood lactate concentrations were determined during exercise and recovery. Maximal power output did not significantly differ after the treatment in either group. The mean individual lactate threshold rose significantly after Cr treatment from 314.3 +/- 5.0 W to 335.6 +/- 7.1 W (p<.01), as compared with 305.0 +/- 6.9 W and 308.9 +/- 5.9 W (ns), before and after placebo ingestion, respectively. During the anaerobic test, the athletes supplemented with creatine were able to continue rowing longer (mean increase, 12.1 +/- 4.5 s; p<.01) than Pl-Group (2.4 +/- 8.2 s; ns). No significant differences were found between groups in blood LA after the all-out exercise. The results indicate that in elite rowers, creatine supplementation improves endurance (expressed by the individual lactate
threshold) and anaerobic performance, independent of the effect of intensive endurance training.

**Lormes W, Buckwitz R, Rehbein H, Steinacker JM (1993)** compared the Gjessing (GE) and the wind resistance (Concept II, CII) rowing ergometers on 11 trained subjects during incremental exercise. Maximum power was 255 (200-370) W on GE, but 294 (204-393) W in CII (median and range, p < 0.05). If power was directly measured by a strain gauge and a displacement transducer in the CII, a 5.1% (3.2%-7.8%) higher maximum performance was obtained (314 [223-413] W, p < 0.05). Maximum stroke rates were higher in GE (33 [27-37]/min) than in CII (29 [24-35]/min, NS). Blood lactate increased faster with work rate and lactic anaerobic threshold was therefore lower in GE. Blood lactate was higher for every heart rate for GE compared to CII. This suggests higher anaerobic effort in GE rowing.

**Bourdin M, Messonnier L, Lacour JR (2004)** validated the laboratory testing used to monitor on water training. The purpose was to test that reference heart rates (HR) determined during an incremental test elicit comparable blood lactate levels ([LA](b)) during a 30 min on water rowing. Blood lactate profile were determined during incremental graded exercise in 14 national and international level oarsmen. The HR corresponding to [LA](b) of 2 and 3 mmol x l(-1) were determined (HRLa2 and HRLa3 respectively). The rowers then performed a 30 min
training session in a boat. Training intensity, as assessed by HR monitors, had to range between HRLa2 and HRLa3. Field [LA](b) (LAF) and HR (HRF) were measured at the end of the training session. LAF was 2.13+/-0.49 mmol x l(-1) (range: 1.43-3.07) and did not differ significantly from 2 mmol x l(-1). HRF (162+/-7.4 beats x min(-1)) ranged from HRLa2 (159+/-9.5 beats x min(-1)) to HRLa3 (171+/-9 beats x min(-1)). HRF was not significantly different from HRLa2. It was concluded that the HR determined during the laboratory testing are valid for monitoring on water training in highly trained rowers.

Y Koutedakis and N C Sharp (1985) undertook a study in which three tests were conducted to assess the effectiveness of three different intensities of exercise both in reducing blood lactic acid (LA) levels and in influencing subjects' heart rate (HR), following a 2000 m race in a rowing boat. In the first and second tests these variables were investigated during a 13 min recovery exercise at 60% and 40% of the preceding maximum rowing speed respectively. In the third test the subjects had a resting recovery. The results include a significant increase (P less than 0.001) in the rate of lactate removal following the 40% recovery compared with the 60% and resting recoveries. The HRs were significantly lower during the last minute of resting recovery compared with 40% and 60% recoveries (P less than 0.001). The same was true when 40% recovery was compared with 60% recovery (P less than 0.001).
0.001). The present data suggest firstly that 40% of the maximum rowing speed is an appropriate pace for effective LA removal and secondly that, at least for trained rowers, 86% of their maximum HR can be taken as an indication of work of intensity at or above anaerobic

J J Forsyth and M R Farrally (2000) examined the validity of using blood taken from the toe for the assessment of plasma lactate concentration in rowers. To achieve this, values were compared with those taken from the fingertip and earlobe. Nine subjects exercised at two separate submaximum workloads on the Concept II rowing ergometer. The loads, each lasting four minutes, elicited mean (SD) heart rate responses of 160.1 (8.5) and 180.1 (5.7) beats/min, which corresponded to 76.4 (6.1)% and 91.9 (4.7)% of the estimated heart rate maximum of the subjects. Blood was simultaneously removed after the cessation of exercise by three experimenters and was analysed for plasma lactate concentration. At 76.4% of estimated heart rate maximum, the mean (SD) plasma lactate concentrations sampled from the fingertip, toe, and earlobe were 6.36 (1.58), 5.81 (1.11), and 5.29 (1.24) mmol/l respectively. At 91.9% of estimated heart rate maximum, respective values were 8.81 (2.30), 8.53 (1.37), and 8.41 (2.35) mmol/l. No significant differences (p>0.05) were found between any of the sites at either work intensity. The toe may offer a practical alternative for assessing the concentration of
lactate during rowing, having the advantage that repeated blood samples can be removed without interruption of the rowing action.

**Urhausen A, Weiler B, Kindermann W (1993)** conducted a study in which the heart rate, blood lactate, and catecholamine responses to rowing on a Gjessing ergometer and in a single scull on the water were compared. Seventeen rowers performed a multistage step test on the ergometer as well as low and high intensity endurance rowing on the water. Seven oarsmen (six with determinations of free plasma adrenaline and noradrenaline) rowed on the ergometer with the same heart rate and duration as on the water. During ergometer endurance rowing, heart rate, lactate, and adrenaline were not significantly different from boat rowing, while plasma noradrenaline was higher. However, at similar lactate levels, heart rate during rowing on the water was approximately 10 beats.min⁻¹ higher than during the ergometer multistage step test, due to the different duration of exercise. Heart rate values based on determination of lactate threshold can be taken as recommendations for low and high intensity endurance training on water. However, because of individual variations in the heart rate-lactate relationship between rowing on the ergometer and in the boat, field evaluation is recommended.

**Coen B, Urhausen A, Kindermann W (2003)** organized a study to develop and validate an incremental graded exercise test performed in the rowing boat(coxless pair) in order to give specific performance
evaluation data. Furthermore, an attempt was made to transfer these data to training recommendations. Thirty-four female rowers of national and international level performed a 4 x 6 min incremental graded exercise test GXT(boat) in coxless pairs on a lake (6 km, no wind, no waves). The boat velocity on the water (V; measured by a speedometer PACE COACH) was increased continuously from 3.55 m x s⁻¹ to 4.03 m x s⁻¹. The individual anaerobic threshold (IAT) was determined by means of the lactate (LA) kinetics during and after exercise. Within 28 days all subjects performed a rowing ergometry test GXT(ergo); Gjessing rowing ergometer: 40 watts increments every 3 min) as well as 70 min of constant endurance training in the boat in moderate velocity (ET; n= 10 pairs because of changing weather conditions). Results for V/LAIHR at IAT are: GXT(boat): 3.84±0.10 m x s⁻¹/2.44 ±0.66 mmol x l⁻¹/172 + 11 min(-¹); GXT(ergo): 206±10 watts/2.53 ±0.40 mmol x l⁻¹/171 +/− 10 min⁻¹ (means±/-SD). The Spearman rank order test showed significant correlations for HR (p < 0.001) and the mean performances of the coxless pairs (p < 0.05). A'5 % lower V during ET lead to a 10% lower HR and a 30% lower LA compared to the values at IAT. In conclusion, both a performance specific evaluation and velocity oriented control of training are possible by means of a 4 x 6 min incremental graded exercise test in coxless pairs. However, this test on the water requires almost perfect
weather conditions. The HR recommendations based on GXT (ergo) were confirmed during GXT (boat).

Messonnier L, Freund H, Bourdin M, Belli A, Lacour JR (1997) established the relationships between individual performance and lactate exchange and removal abilities. The study was conducted on 12 male rowers all subjected to three measurements on a rowing ergometer. An incremental exercise carried out to determine the maximal oxygen uptake (VO\textsubscript{2max}) and the corresponding maximal aerobic power (Pamax), a 2500-m all-out test where the mean work rate (P2500) represented the individual performance, and a 6-min 90% Pamax exercise designed to assess the lactate kinetics during the following 90 min passive recovery were performed. The lactate recovery curves were fitted to the bi-exponential time function: \( \text{La}(t) = \text{La}(0) + A1(1-e^{-\gamma_1 t}) + A2(1-e^{-\gamma_2 t}) \). The velocity constants \( \gamma_1 \) and \( \gamma_2 \) denote the lactate exchange and removal abilities, respectively. The mean value of P2500 sustained by the rowers was 376 +/- 41W (106 +/- 5% of Pamax (P2500%)). P2500 was positively correlated with \( \gamma_2 \) (\( P < 0.05 \)). \( \gamma_1 \) and \( \gamma_2 \) explained 67% of the P2500 variance. P2500% was also correlated with \( \gamma_2 \) (\( P < 0.01 \)). These results suggest that a better performance on the rowing ergometer is associated with improved lactate exchange and removal abilities. Furthermore, the ability to row at high relative work rates was correlated with an increased
lactate removal ability. Training-induced adaptations could explain the high gamma 1 and gamma 2 displayed by the present rowers.

Baldari C, Videira M, Madeira F, Sergio J, Guidetti L (2005) organized a study in which Optimal lactate removal was reported to occur at work-rate between 30% and 70% VO2max. However, it has been recently recommended to quantify exercise intensity not in percentage of VO2max but in relation to validated metabolic reference points such as the individual anaerobic threshold (IAT) and the individual ventilatory threshold (IVT). The purpose of this study was to examine the effect on lactate removal of different recovery work-rates below the IAT defined calculating the difference (DT) between IAT and IVT, then choosing the IVT+50%DT, the IVT and the IVT-50%DT work-rates. Eight male triathletes (VO2max 69.7+/-4.7, VO2IAT 52.9+-/-4, VO2IVT 41.1+/-4.7 mL x kg(-1) x min(-1)), after a 6-min treadmill run at 75% of difference between IAT and VO2max, performed in a random order the following 30-min recovery treatments: 1) run at IVT(plus;50%DT), 2) at IVT, 3) at IVT(-50%DT), 4) passive. Blood lactate was measured at 1, 3, 6, 9, 12, 15, 20, 25, 30 minutes of recovery. All active recovery work-rates (from 50+/-5% to 67+/-4% VO2max) were within the range previously reported for optimal lactate removal, and significantly more efficient than passive recovery on lactate removal curve (% of accumulated lactate above rest value). However, significant differences (P<0.01) were found among
active recovery intensities: the IVT(-50%DT) was the most efficient work-rate from the 9th minute to 30th minute. In triathletes, the IVT(-50%DT) was the optimal work-rate for lactate removal; moreover none of the studied active work-rate showed further lactate decrease after the 20th minute of recovery.

Gmada N, Bouhlel E, Mrizak I, Debabi H, Ben Jabrallah M, Tabka Z, Feki Y, Amri M (2005) conducted a study with the purpose to determine the effect of different modalities of individualized active recovery on blood lactate disappearance after supramaximal exercise in subjects with different levels of aerobic fitness. Fourteen healthy subjects (7 trained and 7 untrained subjects mean age 20 +/- 1.5 and 19.5 +/- 1.5, respectively) participated in this study. They performed three supramaximal intermittent exercises at 60 % of the time to exhaustion at 120 % of the maximum aerobic power (MAP) with 5-min recovery periods (2 x 5 min). The third exercise was followed by 20 min of recovery. The effects of four types of recovery were compared in trained and untrained subjects: passive recovery (PR), an active recovery at an intensity corresponding to the first anaerobic ventilatory threshold minus 20 % (VT1), an active recovery at an intensity corresponding to the second anaerobic ventilatory threshold minus 20 % (VT2) and a combined active recovery (CR) which consisted of 7 min at VT2 followed by 13 min at VT1. Blood lactate levels were measured at rest.
and during the recovery periods. Peak blood lactate after supramaximal exercise was observed significantly earlier with VT2 and CR (4th min) than VT1 and PR (7th min) in trained and in untrained subjects. Combined active recovery (CR) showed a significantly faster lactate disappearance than did PR, VT1, or VT2 from the 7th min of recovery in trained subjects (p < 0.05) and at the 20th min in untrained subjects (p < 0.05). CR and VT2 conditions showed earlier peak blood lactate (4th min) than PR or VT1 (7th min). Blood lactate disappearance was faster in trained than untrained subjects during combined active recovery. This result suggests that the level of physical fitness plays an important role mainly in the pattern of blood lactate decrease during combined active recovery.

Stamford BA, Weltman A, Moffatt R, Sady S (1981) had undertaken this study to determine the effects of resting and exercise recovery above [70% of maximum O2 uptake (VO2 max)] and below [40% of VO2 max] anaerobic threshold (AT) on blood lactate disappearance following maximal exercise. Blood lactate concentrations at rest (0.9 mM) and during exercise at 40% (1.3 mM) and 70% (3.5 mM) of VO2 max without preceding maximal exercise were determined on separate occasions and represented base lines for each condition. The rate of blood lactate disappearance from peak values was ascertained from single-component exponential curves fit for each individual subject for
each condition using both the determined and resting base lines. When
determined base lines were utilized, there were no significant differences
in curve parameters between the 40 and 70% of VO2 max recoveries, and
both were significantly different from the resting recovery. When a
resting base line (0.9 mM) was utilized for all conditions, 40% of VO2
max demonstrated a significantly faster half time than either 70% of VO2
max or resting recovery. No differences were found between 70% of VO2
max and resting recovery. It was concluded that interpretation of the
effectiveness of exercise recovery above and below AT with respect to
blood lactate disappearance is influenced by the base-line blood lactate
concentration utilized in the calculation of exponential half times.

Schmid A, Huonker M, Aramendi JF, Klüppel E, Barturen
compared the deflection point (DP) of the heart rate in relation to the
work rate (WR) of 8 male endurance-trained paraplegics and 11 male
physically active sports students was investigated during nonsteady-state
incremental arm cranking ergometry (IT) and compared to the 4 mmol x
l(-1) blood lactate concentration threshold and to blood lactate
concentration in steady-state exercise (SST). Heart rate, and lactate
concentration from capillary blood, were determined at rest, during IT
and SST. The DP was calculated by linear regression analysis of the heart
rate during IT. The SST consisted of three consecutive exercise
intensities over a period of 8 min at exercise intensities of 10 W below, and at 10 W above the work rate at deflection point (WRDP). No difference was found between the paraplegics and non-handicapped subjects regarding heart rate and blood lactate concentration at rest and during exercise. A DP was established in all the paraplegics and in 72.7% of the non-handicapped subjects, but lactate accumulation was observed in 75% of the paraplegics and in 62.5% of the non-handicapped subjects at the lowest intensity of SST. In summary, endurance-trained paraplegics with an injury level below T5 showed heart rate and blood lactate concentration values comparable to non-handicapped subjects during IT. A linear increase at moderate exercise intensities and a leveling-off at higher to maximal intensities could be identified in all the paraplegics and in 72.7% of non-handicapped subjects. The determination of the anaerobic threshold by DP should be applied with caution, since no causal relationship of DP and the anaerobic threshold was found and the WRDP tended to overestimate threshold values.

Evans BW, Cureton KJ (1983) conducted this study to investigate the effect of physical conditioning on the rate of blood lactate disappearance during recovery from supramaximal exercise. The rate of blood lactate disappearance was determined in 11 female and 4 male subjects before and after a 6-week conditioning programme. Blood samples were taken during the 30 minutes following supramaximal
exercise during both passive (resting) and active recoveries. Pre-test active recovery was performed at 25% VO$_2$ max; post-test active recovery was performed at both the same absolute and relative intensities (% VO$_2$ max) as during the pre-test. Eight of the subjects trained 4 days/week for 6 weeks with high-intensity interval bicycle ergometer exercise, and 7 subjects served as controls. The conditioning programme significantly (p less than .05) increased VO$_2$ max by 6.7 ml/kg.min (15%) and work capacity on the cycle ergometer by 2.8 minutes (27%). Physical conditioning did not affect significantly (p less than .05) the rate of blood lactate disappearance measured during passive recovery or during active recovery at the same absolute intensity, but increased significantly (p less than .05) the rate of blood lactate disappearance during active recovery performed at the same relative exercise intensity. The increased disappearance rate following conditioning was attributed to the higher absolute intensity of recovery work performed.

Wasserman K, Stringer WW, Casaburi R, Koike A, Cooper CB (1994) compared the physiological and biochemical basis of the anaerobic threshold (AT), achieved during physical exercise. The lactate concentration is approximately the same at rest in relatively fit adults, in normal sedentary subjects in adult patients with heart disease. But during exercise, the increase of lactate is inversely related to the physical fitness of the individual. During incremental work, the lactate concentration
increases initially very little until a distinct metabolic rate (VO₂ AT) is reached at which lactate starts to increase steeply (anaerobic threshold/AT; VO₂ AT). Above the anaerobic threshold, accelerated glycolysis increases muscle lactic acidosis. This acidosis is buffered primarily by bicarbonate. The bicarbonate-derived CO₂ causes an increased alveolar CO₂ output relative to O₂ uptake. Oxygen uptake is increased virtually linearly with work rate in healthy subjects with a slope of approximately 10 ml O₂/min/Watt. VCO₂ starts to increase more steeply in the mid-work-rate range after an initial linear behavior. This steepening is caused by an increased CO₂ production from the HCO₃-buffering of lactic acid for the range of work rates above the AT. Below the AT, the slope of increase in VCO₂ is 1 or slightly less, averaging 0.95. Above the AT, it is greater than 1. The submaximal exercise protocol for the determination of AT includes a period of 2-3 min of unloaded cycling, a ramp program with x Watt increase/minute and a recovery period of 2 min. X is the rate of work rate increase per min, so that the incremental period of the exercise test lasts 8-10 min, stressing the patient for only a short time. The anaerobic threshold can be determined during the ramp program using the following four parameters: 1) steeper increase of VCO₂ as compared to VO₂ (V-slope-method); 2) respiratory exchange ratio = 0.95; 3) PETO₂ increase; 4) VE/VO₂ increase. The V-slope-method can be successfully applied, not only in healthy volunteers,
but also in patients suffering from cardiac and/or pulmonary (breathing abnormalities) diseases. The so far published data show that the anaerobic threshold in healthy people and patients is a highly reproducible, accurately measurable, securely achievable parameter for the non-invasive evaluation of the individual cardiopulmonary exercise capacity.

Roth W, Schwanitz P, Pas P, Bauer P (1993) examined the force-time characteristics of the rowing stroke in a coxless pair. Sixteen highly trained rowers were evaluated in their usual training positions (stroke or bow). Stroke rowers had higher stroke speed and stroke force in the first part of the stroke than bow rowers. This finding was more prominent during competition speed rowing than during endurance training. Higher blood lactate levels and lower base excess were found at both speeds in stroke rowers. During and incremental ergometer rowing test, lactate performance curves were shifted to the left in the stroke rowers. Analysis of morphometric data in the left deltoid muscle demonstrated higher FT fiber content and lower oxidative fiber capacity and fiber areas in the stroke rowers. The results demonstrate adaptation to years of training in a specific boat position.

Yoshida T, Suda Y, Takeuchi N (1982) assessed the effect of endurance training based upon the intensity as determined by the arterial blood lactate concentration (LA). Seven healthy male college students performed endurance training on a Monark bicycle ergometer for 15 min
on 3 days/week for 8 weeks, at an intensity corresponding to 4 mmol X l-1 arterial blood LA determined during an incremental exercise test (25 watts increment every minute on a bicycle at 50 rpm). Another six male students served as the control group. To assess the training effect, both an incremental exercise test and a submaximal exercise test were performed before and after the endurance training. In the incremental exercise test, VO2max, VE at VO2max, anaerobic threshold (AT), and the onset of respiratory compensation for metabolic acidosis (RCMA) were measured. AT was determined as the point at which arterial LA rose above the resting value, and RCMA was determined as the point at which Paco2 decreased during the incremental exercise test. After training, AT increased significantly (37% increment expressed in VO2, p less than 0.05). There was a significant increase (p less than 0.05) in RCMA (17%) and VO2max (14%). This training decreased VO2 (4%), VE (15%), heart rate (10%), respiratory exchange ratio (5%), and LA (23%) significantly (p less than 0.05) during the submaximal exercise test after training. On the other hand, there were no significant changes in the control group through the period when the training group performed their training. These results showed that the endurance training intensity corresponding to 4 mmol X l-1 arterial blood LA was effective for the improvement in AT as well as VO2max. It is suggested that the present training regimen could delay the onset of anaerobic glycolysis, thus shifting AT to the
higher workload and decreasing LA at a given submaximal exercise after training.

Tegtbur U, Machold H, Meyer H, Storp D, Busse MW (2001) conducted a study in which Intensive physical exercise improves cardiac perfusion, skeletal muscle function and risk factors in patients with coronary artery disease (CAD). Otherwise, overdosed intensity can induce training adaptation as well as cardiac events. Therefore, we tested whether exercise intensity corresponding to an equilibrium between lactate production and elimination from the blood during incremental exercise tests represented the blood lactate [Lac-]B steady-state intensity during constant physical training. Randomized into two groups with 30 CAD patients each (T1: 25 male, 5 female; 59 +/- 7 years; T2: 26 male, 4 female; 60 +/- 9 years), the patients initially performed two successive incremental exercise tests. In the first test, workload was increased stepwise until exhaustion or symptom limitation (maximal workload: T1 142 +/- 48 watts, T2 145 +/- 45 watts) with the corresponding [Lac-]B accumulation of up to 6.7 +/- 2.6 (T1) or 6.5 +/- 2.0 (T2) mmol/l, respectively. After a seven minute active rest the second test began with 25 watts, increased with 5 (maximum workload in first test < 100 watts) or 10 watts per minute, respectively. During lower intensities in the second test, [Lac-]B initially decreased to an individual lactate minimum intensity (workload at LMI 83 +/- 32 in T1 or 86 +/- 29 in T2 watts,
respectively; [Lac-]B at LMI 4.6 +/- 2.2 and 4.9 +/- 1.8 mmol/l, respectively) and then increased again. To check if the individual LMI represented the [Lac-]B steady-state workload in constant workload exercise, the patients performed 30 min constant load tests with the LMI (CT1) or a 30 min constant load test with an intensity 10% above the LMI (CT2), respectively. The workload in CT1 was 83 +/- 32 watts with a mean exercise time of 29.0 +/- 1.7 min. After 10 min of exercise the [Lac-]B steady state was reached at 3.3 +/- 1.4 mmol/l with no further increase in the last 20 min. The mean workload in CT2 was 95 +/- 31 watts with an exercise time of 23.3 +/- 8.3 min (p < 0.01). [Lac-]B increased from 4.4 +/- 1.7 mmol/l after 10 min to 4.7 +/- 2.0 mmol/l at the end (p < 0.01). Fifty percent of patients stopped CT2 before the 30 minute end. The results indicates that the LMI, estimated during lactic acidosis in two successive incremental tests, represented the individual lactate steady-state intensity also during constant load exercise. Therefore, training regimens for CAD patients could be deduced from LMI.

Urhausen A, Weiler B, Coen B, Kindermann W. (1994) investigated the concentrations of free plasma catecholamines (CAT), adrenaline and noradrenaline, in comparison to heart rate and lactic acid concentrations during endurance exercises (EE) of different intensities related to the individual anaerobic threshold (IAT). A group of 14
endurance trained male athletes took part in the tests on a treadmill. After an exhausting incremental graded test (increasing 0.5 m.s⁻¹ every 3 min) to determine the IAT, the subjects performed EE of 45 min in randomized order with intensities of 85%, 95%, 100% and 105% (E85-E105) of the IAT. The heart rate and CAT increased continuously during all EE. The CAT reacted sensitively to EE above IAT (E105) and showed an overproportional increase in comparison to EE performed with an intensity at or below IAT. At the same time, at exercise intensities up to IAT (E85-E100) a lactate steady state was observed whereas mean lactate concentrations increased during E105. The changes of lactate concentration allowed a better differentiation between E85-E100 as CAT measurements. In E95, E100 and E105 there was a partial overlap of heart rate, which in contrast to lactate concentration only differed by about 5%, so that small variations in heart rate could have coincided with considerable differences of exercise intensity when working at intensities near or above IAT. It was concluded that the range of IAT seemed to represent a real physiological breakpoint which corresponded to the aerobic-anaerobic transition.

_Tegtbur U, Busse MW, Braumann KM_(1993)_ observed during an incremental exercise test after a preceding bout of maximum exercise, blood lactate initially decreases to an individual minimum and then increases again. To determine whether this minimum represents an
individual equilibrium between lactate production and catabolism during constant load exercise, the following field tests were performed: in 25 runners and five basketball players (series 1) the speed corresponding to the individual lactate minimum (LM) was measured in test 1 (incremental test after exercise induced lactic acidosis). On two occasions, two constant speed runs over 8 km were performed, one using the LM speed (LMS) (test 2), and another at a running speed of 0.2 m.s-1 above the LMS (test 3). Results of runners/basketball players: blood lactate concentration ([Lac-]B) in test 2 changed from 3.6/4.9 mmol.l-1 to 4.0/4.9 mmol.l-1 during the last 4.8 km, in test 3 from 4.6/4.6 mmol.l-1 to 6.5/6.9 mmol.l-1. These results indicate: 1) the LM speed in test 1 corresponds to a maximum lactate steady state speed during constant load exercise; 2) only a slight speed increase above the LM speed results in continuous marked [Lac-]B increase and earlier exhaustion. Variation of the increment duration in 13 males (series 2) shows no change of the LMS using 800-m and 1200-m increments (4.49 and 4.44 m.s-1) but a marked shift to higher speed using 400-m increments (4.96 m.s-1). Effects of low muscle glycogen stores on the LMS were determined in 10 males (series 3).

Conducted this study to estimate the characteristic exercise intensity (WCL) which produces the maximal steady state of blood lactate
concentration (MLSS) from submaximal intensities of 20 min carried out on the same day and separated by 40 min. Ten fit male adults [maximal oxygen uptake (VO₂max) 62 (SD 7) ml.min⁻¹.kg⁻¹] exercised for two 30-min periods on a cycle ergometer at 67% (test 1.1) and 82% of VO₂max (test 1.2) separated by 40 min. They exercised 4 days later for 30 min at 82% of VO₂max without prior exercise (test 2). Blood lactate was collected for determination of lactic acid concentration every 5 min and heart rate and O₂ uptake (VO₂) were measured every 30 s. There were no significant differences at the 5th, 10th, 15th, 20th, 25th, or 30th min between VO₂, lactacidaemia, and heart rate during tests 1.2 and 2. Moreover, we compared the exercise intensities (WCL) which produced the MLSS obtained during tests 1.1 and 1.2 or during tests 1.1 and 2 calculated from differential values of lactic acid blood concentration ([LA-b]) between the 30th and the 5th min or between the 20th and the 5th min. There was no significant difference between the different values of WCL [68 (SD 9), 71 (SD 7, 73 (SD 6), 71 (SD 11)% of VO₂max] (ANOVA test, P < 0.05). Four subjects ran for 60 min at their WCL determined from periods performed on the same day (test 1.1 and 1.2) and the difference between the [la-b] at 5 min and at 20 min (delta ([la-b])) was computed.

Carter H, Jones AM, Doust JH (2000) conducted this study to assess the responses of blood lactate and pyruvate during the lactate minimum speed test. Ten participants (5 males, 5 females; mean +/- s:
completed: (1) the lactate minimum speed test, which involved supramaximal sprint exercise to invoke a metabolic acidosis before the completion of an incremental treadmill test (this results in a 'U-shaped' blood lactate profile with the lactate minimum speed being defined as the minimum point on the curve); (2) a standard incremental exercise test without prior sprint exercise for determination of the lactate threshold; and (3) the sprint exercise followed by a passive recovery. The lactate minimum speed (12.0±1.4 km x h(-1)) was significantly slower than running speed at the lactate threshold (12.4±1.7 km x h(-1)) (P < 0.05), but there were no significant differences in VO₂, heart rate or blood lactate concentration between the lactate minimum speed and running speed at the lactate threshold. During the standard incremental test, blood lactate and the lactate-to-pyruvate ratio increased above baseline values at the same time, with pyruvate increasing above baseline at a higher running speed. The rate of lactate, but not pyruvate, disappearance was increased during exercising recovery (early stages of the lactate minimum speed incremental test) compared with passive recovery. This caused the lactate-to-pyruvate ratio to fall during the early stages of the lactate minimum speed test, to reach a minimum point at a running speed that coincided with the lactate minimum speed and that was similar to the point at which the lactate-to-pyruvate ratio increased above baseline in
the standard incremental test. Although these results suggest that the mechanism for blood lactate accumulation at the lactate minimum speed and the lactate threshold may be the same, disruption to normal submaximal exercise metabolism as a result of the preceding sprint exercise, including a three- to five-fold elevation of plasma pyruvate concentration, makes it difficult to interpret the blood lactate response to the lactate minimum speed test. Caution should be exercised in the use of this test for the assessment of endurance capacity.

Vermulst LJ, Vervoorn C, Boelens-Quist AM, Koppeschaar HP, Erich WB, Thijssen JH, de Vries WR. (1991) organized a study preceding the 1988 Olympic Games in which 6 elite female rowers were regularly subjected to an exercise test on a rowing ergometer (REM-test) with a time interval of about 5 weeks. Daily training volume was analysed in terms of rowed kilometres (RKM) and training time (TOTMIN, rowing and land training). The purpose of this study was to investigate the training volume during a season and to study possible changes in the working capacity of elite female rowers. The REM-test consisted of 3 consecutive blocks: 3 min warming up, 5 min standard load at anaerobic threshold and 2 min "all-out". Blood lactic acid concentration (LA) was determined for the construction of a LA-power curve. The power at 4.0 mmol/l (P4) was estimated as a measure of the aerobic capacity. The "all-out" score was used for calculating the
maximal power (PM). Results show that both RKM and TOTMIN increase (range resp. 40-400% and 20-25%) when compared with the initial value. P4 also increases, in parallel with changes in both RKM and TOTMIN, with 8-10% of the initial value. PM increases continuously during the season up to 10% of its initial value. However, based on maximal heart rate and lactate values, it is concluded that PM was maximal in only 15% of the tests. Our data suggests that evaluation of training volume in elite female rowers is better done with P4 than with PM. The behaviour of P4 shows a parallel with the seasonal changes in the training load.

Davis HA, Bassett J, Hughes P, Gass GC (1983) investigated Venous lactate concentration and ventilatory responses to progressively increased work rates were studied in 16 men who performed an incremental exercise test to exhaustion on an electrically braked cycle ergo meter. In this test the characteristic curvilinear increase in venous lactate concentrations was observed. In addition to the anaerobic threshold (AT), a second breakpoint was observed and named the lactate turn point (LTP). Eight of the 16 subjects performed a second incremental exercise test initiated during lactic acidosis. In this test the direction of change in venous lactate concentrations was different. The work rate at which lactate concentrations again increased, after a steady decline (previously described as the AT2), was similar to the work rate
established for the LTP in the first test. In the second test removal of lactate was demonstrated at work rates exceeding the AT. Although the lactate response to the two tests was different the pattern of change was similar, with the two breakpoints occurring at the same work rates. Collectively these results lend a measure of support to the hypothesis of a positive relationship between the AT, LTP, and a pattern of recruitment of motor units with different enzyme profiles. Both the AT and LTP were predictable from the ventilatory response to incremental exercise.

Karu T, Nurmekivi A, Lemberg H, Pihl E, Jürimäe T (2000) conducted this study to investigate how heart rate (HR) and blood lactate (LA) concentrations are associated with perceived readiness ratings (PRR) to begin a new run during recovery after four different intensity steady-state 2000 m runs in college-level male middle-distance runners (n=15). A typical 4x2000 m run test with stepwise increasing speed was used on the indoor track (150 m lap). A new PRR scale was administered at each minute of recovery. The scale ranges from 1 to 5 points (from "not at all ready to begin" to "completely ready to begin"). Blood LA concentrations were measured immediately after runs and in the 3rd min of recovery after the first and second runs. In case of the third and fourth runs, blood LA was measured immediately after the runs and in the 3rd and 6th min of recovery. HR was recorded at the end of every minute of recovery. Highly significant inverse relationships were revealed between
PRR, blood LA concentrations and HR during recovery (r>0.9 as a rule). After the third and the fourth 2000 m runs, where intensity was higher than LA threshold, PRR increased during 6 min up to 4.8+/-.0.4 and 4.5+/-.0.6, respectively, while HR fell below 120 beats x min\(^{-1}\). However, blood LA concentration remained high. The reliability of the new PRR scale (tested on four runners), during recovery was very high (r=0.98). These results suggest that the PRR scale can be used by runners to determine the optimal duration of resting intervals between runs.

**Chmura J, Nazar K, Kaciuba-Uścilko H (1994)** conducted this study in which Twenty-two male soccer players (mean age 21.3 yrs) performed an incremental, multistage bicycle ergo meter exercise test with work load increasing by 50 W, until volitional exhaustion. The exercise stages lasted 3 min and were separated by 1 min resting periods. Before exercise and during each load an audio-visual five-choice reaction task was administered to assess subjects' psychomotor performance. During resting intervals venous blood samples were taken for lactate (LA), adrenaline (A) and nor adrenaline (NA) determinations. It was found that reaction time (RT) decreased gradually during exercise reaching its minimum (approx. 87% of pre-exercise value) at load 236 W (approx. 75% \(VO_{2}\)max, HR 164 beats/min). Then, it increased rapidly, exceeding the resting level by 18%. The work load and heart rate (HR) associated with the minimal RT were higher (p < 0.001) than work load
and HR associated with the LA threshold (by 46 W and 17 beats/min, respectively). Plasma A and NA showed an exponential increase during exercise with thresholds at 204 and 208 W, respectively (HR 149 and 154 beats/min). Work load at which plasma NA threshold occurred was significantly higher than the LA threshold but it did not differ from the work load associated with the minimal RT. Conversely, plasma A threshold was lower than the load of the minimal RT but did not differ significantly from LA threshold. It is concluded that young athletes continue to improve their psychomotor performance during exercise even at heavy work loads exceeding anaerobic, and plasma adrenaline thresholds. A relationship between reaction time and plasma catecholamines fits the U-shape curve.

Bonen A, Campbell CJ, Kirby RL, Belcastro AN (1979) concluded that the lactate (La) removal from blood occurs significantly faster during moderate exercise than at rest. However, under both conditions there are considerable inter-individual differences in La removal. These differences in man may depend on the slow-twitch (ST) fiber content of muscle (X1), the La concentration in blood (X2), and the intensity of the recovery exercise (X3). Therefore, multiple regression models were obtained to describe La removal rates with these variables. In 10 women La concentrations were increased via a 6 min bicycle ergometer ride (87% VO₂ max) and blood La concentrations were measured
every 5 min during 20 min resting and active recovery periods (29--49% \( VO_2\max \)). For resting recovery only the initial LA concentration after the 6 min exercise provided a significant description for La removal in 8 subjects (\( P = 0.03 \)). However, for the active recovery a highly significant description for La removal was obtained: La removal rate (mM/1 . min) = 0.773 \times 10^{-2}X_1 + 0.321 \times 10^{-1}X_2 - 0.120 \times 10^{-1}X_3 + 0.202 (R = 0.91; P = 0.01). The statistical independence (P greater than 0.010) of each of these variables in the model suggests that each is contributing uniquely to the total removal rate of La observed during an active recovery period. The relationship between LA removal and %ST fibers may be related to the metabolic and anatomical features of these fibers, the La concentration probably reflects the significance of the mass action effect of La, and the intensity of exercise reflects the role of the muscle's metabolic rate. The present results illustrate that the removal of blood lactate is influenced by the interactive effects of the intensity of the recovery exercise, blood lactate concentration and the ST fiber content of muscle.

Belcastro AN, Bonen A (1975) examined after a standardized 6-min bicycle ergometer exercise (89% \( VO_2\max \)) lactic acid removal rates were compared during recovery at rest and exercise at 29.7, 45.3, 61.8, and 80.8% \( VO_2\max \), and twice while the subjects (\( N = 7 \)) regulated their own recovery exercise. Blood samples were taken after the
standardized exercise and every 5 min during the 30-min recovery periods. During the controlled recovery periods lactic acid removal rates were dependent on the intensity of the recovery ($Y' = 0.103 + 0.218\chi - 0.464 \times 10^{-2}\chi^2 + 0.252 \times 10^{-4}\chi^3$). Optimal removal was predicted to occur at 32% $VO_2\text{max}$. Removal rates during the self-regulated recoveries were not different ($P > 0.05$), but these removal rates were faster than during recovery at rest and exercise at 61.8 and 80.8% $VO_2\text{max}$ ($P < 0.01$). Removal rates during the self-regulated recovery and recovery at 29.7 and 45.3% $VO_2\text{max}$ were not different ($P > 0.05$). The subjects were therefore able to remove lactic acid effectively when selecting their own recovery exercise.

Clingeleffer A, McNaughton LR, Davoren B. (1994) organized a study in which eight highly trained male kayakers were studied to determine the relationship between critical power (CP) and the onset of blood lactate accumulation (OBLA). Four exercise sessions of 90 s, 240 s, 600 s, and 1200 s were used to identify the CP of each kayaker. Each individual CP was obtained from the line of best fit (LBFCP) obtained from the progressive work output/time relationships. The OBLA was identified by the 4 mmol.l-1 blood lactate concentration and the work output at this level was determined using a lactate curve test. This consisted of paddling at 50 W for 5 min after which a 1-min rest was taken during which a 25-microliters blood sample was taken to analyse
for lactate. Exercise was increased by 50 W every 5 min until exhaustion, with the blood sample being taken in the 1-min rest period. The exercise intensity at the OBLA for each subject was then calculated and this was compared to the exercise intensity at the LBFCP. The intensity at LBFCP was found to be significantly higher (t = 2.115, P < 0.05) than that at the OBLA of 4 mmol/l-1. These results were further confirmed by significant differences being obtained in blood lactate concentration (t = 8.063, P < 0.05) and heart rate values (t = 2.90, P < 0.05) obtained from the exercise intensity at LBFCP over a 20-min period and that of the anaerobic threshold (Th(an)) parameters obtained from the lactate/heart rate curve.

Ahmaidi S, Granier P, Taoutaou Z, Mercier J, Dubouchaud H, Prefaut C (1996). conducted this study to investigate the effects of active recovery (AR) on plasma lactate concentration [LA] and anaerobic power output as measured during repeated bouts of intense exercise (6 s) against increasing braking forces. Ten male subjects performed two randomly assigned exercise trials: one with a 5-min passive recovery (PR) after each exercise bout and one with a 5-min active recovery (AR) at a workload corresponding to 32% of maximal aerobic power. Blood samples were taken at rest, at the end of each exercise bout (S1) and at the 5th minute between bout-recovery (S2) for plasma lactate assay. During the tests, [LA]S1 was not significantly different after AR and PR, but [LA]S2 was significantly lower after AR for power outputs obtained
at braking forces 6 kg (5.66 +/- 0.38 vs 7.56 +/- 0.51 mmol.l-1) and peak anaerobic power (PANP) (6.73 +/- 0.61 vs 8.54 +/- 0.89 mmol.l-1). Power outputs obtained at 2 and 4 kg did not differ after AR and PR. However, when compared with PR, AR induced a significant increase in both power outputs at 6 kg (842 +/- 35 vs 798 +/- 33 W) and PANP (945 +/- 56 vs 883 +/- 58 W). These results showed that AR between bouts of intensive exercise decreased blood lactate concentration at high braking forces. This decrease was accompanied by higher anaerobic power outputs at these forces.

Falk B, Einbinder M, Weinstein Y, Epstein S, Karni Y, Yarom Y, Rotstein A (1995) Organized this study to examine the effect of ambient heat on the decrease in blood lactate concentration ([LA]bl) during passive and during active recovery. Ten trained men performed six 1-min bouts of exercise at 100% VO2peak on a cycle ergo meter, with 1-min rest between the bouts. Each subject exercised twice in thermo neutral (22 degrees C, 40% RH, TN), and twice in hot (35 degrees C, 30% RH, H) conditions. Exercise was followed by either 40 min of passive recovery (sitting) or by 20 min active recovery (cycling at 35% VO2peak) or 20 min passive recovery, named thereafter, 'active recovery'. Capillary blood lactate was measured before, 1 min after, and every 5 min during recovery. Heart rate (HR), rectal and skin temperatures (Tre, Tsk) were monitored continuously. VO2 was measured prior to exercise,
during the last exercise bout, the first 10 min of recovery, and periodically thereafter. Post-exercise [LA]bl was similar in all treatments (13.5 +/- 1.8, 13.0 +/- 1.3, 14.8 +/- 4.1, 13.3 +/- 2.6 mmol.l-1 for TN-active, TN-passive, H-active and H-passive, respectively). [LA]bl was significantly lower during active, compared to passive recovery in both, TN and H conditions. Environmental heat did not independently affect [LA]bl during passive or active recovery. Exercise resulted in an elevation in all treatments, with a significantly higher Tre during active recovery in H compared to the other sessions. Likewise, no differences in HR and in VO2 were observed between H and TN conditions during active nor during passive recovery.

Simões HG, Grubert Campbell CS, Kokubun E, Denadai BS, Baldissera V (1999) compared the equilibrium point between blood lactate production and removal (LA-(min)) and the individual anaerobic threshold (IAT) protocols have been used to evaluate exercise. During progressive exercise, blood lactate [LA-]b, catecholamine and cortisol concentrations, show exponential increases at upper anaerobic threshold intensities. Since these hormones enhance blood glucose concentrations [Glc]b, this study investigated the [Glc] and [LA-]b responses during incremental tests and the possibility of considering the individual glucose threshold (IGT) and glucose minimum (Glc(min)) in addition to IAT and LA-(min) in evaluating exercise. A group of 15 male endurance runners
ran in four tests on the track 3000 m run (v3km); IAT and IGT - 8 x 800 m runs at velocities between 84% and 102% of v3km; LA-(min) and Glc(min) - after lactic acidosis induced by a 500-m sprint, the subjects ran 6 x 800 m at intensities between 87% and 97% of v3km; endurance test (ET) - 30 min at the velocity of IAT. Capillary blood (25 microl) was collected for [La-]b and [Glc]b measurements. The IAT and IGT were determined by [LA-]b and [Glc]b kinetics during the second test. The LA-(min) and Glc(min) were determined considering the lowest [LA-] and [Glc]b during the third test. No differences were observed (P < 0.05) and high correlations were obtained between the velocities at IAT [283 (SD 19) and IGT 281 (SD 21) m. x min(-1); r = 0.096; P < 0.001] and between LA-(min) [285 (SD 21)] and Glc(min) [287 (SD 20) m. x min(-1) r = 0.77; P < 0.05]. During ET, the [La-]b reached 5.0 (SD 1.1) and 5.3 (SD 1.0) mmol x l(-1) at 20 and 30 min, respectively (P > 0.05). We concluded that for these subjects it was possible to evaluate the aerobic capacity by IGT and Glc(min) as well as by IAT and LA-(min).

Oja P, Kukkonen-Harjula K, Nieminen R, Vuori I, Pasanen M (1988) conducted a study in which the heart rate of eleven 39- to 53-year-old regularly exercising but non athletic men was recorded during mass events of 132-km cycling, 35-km rowing, 33-km running, and 90-km cross-country skiing during 1 year. These measurements were related to the cardio respiratory response in respective maximal exercise tests to
determine and compare the strain of the four events. The mean event time of the subjects was 4 h 58 (+/- 34) min for cycling, 4 h 20 (+/- 35) min for rowing, 3 h 30 (+/- 29) min for running, and 8 h 29 (+/- 49) min for skiing. The respective mean heart rates were 153 (+/- 10), 137 (+/- 15), 159 (+/- 8), and 145 (+/- 5) bts/min, which represented 79.3 (+/- 6), 72.9 (+/- 13), 85.7 (+/- 4), and 72.8 (+/- 7) %VO$_2$ max as determined from the event-specific HR/VO$_2$ regression line. The proportion of event heart rates above the level representing the 90% event-specific maximal heart rate was 31.2% (+/- 19%) in cycling, 17.9% (+/- 26%) for rowing, 59.7% (+/- 24%) for running, and 21.6% (+/- 23%) for skiing. A statistical comparison of the mean event heart rates indicated that heart rate was lower in rowing than in jogging (P less than 0.01) and in cycling (P less than 0.05) and also lower in skiing (P less than 0.01) than in jogging. The present results showed that the cardio respiratory strain of middle-aged nonathletic men during long-distance mass events of cycling, jogging, and skiing is high and relatively comparable to that of well-conditioned athletes.