Chapter - II

Review of Related Literature
CHAPTER – II

REVIEW OF RELATED LITERATURE

A study of relevant literature is an essential step to get a full picture of what has been done with regard to the problem under study. Such a review brings out a deep and clear perspective of overall field.

The review of literature is instrumental in selection of the topic, transaction of hypothesis and deductive reasoning leading to the problem. It helps to get a clear idea and supports the findings with regard to the problem under study.

The following materials collected from the views expressed by the personalities provide a background information to the study and help us to understand the various training methods on physiology, kinanthropometric, and performance variables. The experts and research workers in the field of physical education are of primary importance to the present study.

2.1 STUDIES ON PHYSIOLOGICAL VARIABLES

Mcnaughton et al. (1996) conducted a study to investigate the effects of different pedaling speeds on the power duration relationship during high intensity cycle ergometry with pedal cadences 50 (low), 90 (intermediate) and 110 (high) r min.\(^1\). This hyperbolic power duration relationship can be described (as \(p=\text{phip A}) t=W'\), where \(p=\text{power in put, } t=\text{time to exhaustion, and } \text{phip A and } W'\), are constants. Eight volunteer male subjects aged 24 ± 2.6 years, with no
Competitive cycling training took part in this study and each under took thirteen
tests on a lode BV Excalibur sport vl.52 cycle ergometer over an eight week
period. The first exercise bout was a 30 w min\(^{-1}\) incremental cycle at 50 r. min\(^{-1}\)
to volitional fatigue. This allowed the identification of a range of power out put
that would be used to construct and examine the power duration relationships for
each subject at 50, 90 and 110 r. min\(^{-1}\). At both 50 and 90 r.min\(^{-1}\), power outputs
of 30 W above and below and 60W above the highest work rate, as well as the
maximum work rate achieved during the incremental exercise test were chosen,
while at 110 r.min\(^{-1}\), the power out put chosen were 25 W above and below as
well as 50 w above the highest work rate achieved during the incremental exercise
test and also the maximum work rate achieved during the incremental exercise test
were chosen. These four work rates for each pedaling frequency were chosen
because they would have exercise times to exhaustion in the range of 1-10 times.
Each exercise bout was preceded by four minutes of unloaded cycling and then the
work rate was adjusted quickly to the desired load setting by the previously
programmed computerized ergometer. The results of this work indicate that for
the group of subjects studied, pedaling a cycle ergometer at 50 r.min\(^{-1}\) allows
subjects to a pedal for a significantly greater time than when pedaling at either 90
or 110r min\(^{-1}\). Phip A at 50r. min\(^{-1}\) was significantly greater than when pedaling
at either 90 (F(1,21) = 7.47, P<0.01) or 110r.min\(^{-1}\) (F(1,21) = 10.83 P<0.0005).
There was no significant (P>0.22) difference between Phip A at 90 and
110r-min\(^{-1}\), F(1,21) = 1.36 W' however, was not significantly different when the
data for 50 r.min\(^{-1}\), 90 r.min\(^{-1}\) and 110 r.min\(^{-1}\) were compared (F50r.min\(^{-1}\)
their hypothesis, that endurance performance was reduced when recreational cyclist pedal at a high cadence when compared to a low cadence was correct. Maximum sustainable power output using cycle ergometer was higher at 50 r.min.\(^{-1}\) than at either 90 or 110 r.min.\(^{-1}\). At the intermediate cadence endurance was better than at the high but worse than at low cadence. In conclusion, during endurance cycling, recreational cyclist should pedal at lower rather than higher cadence.

Susan et al. (1995) examined cardiorespiratory and physiologic responses to progressive incremental exercise using a variable resistance rowing ergometer and a cycle ergometer in six experience female masters level rowers. Maximal oxygen uptake (VO\(_2\) Max: 338 ± 7.3, 335 ± 6.6m/kg-1 min.\(^{-1}\)) and minute ventilation (\(\text{Ve}_{\text{max}}\) : 86.1 ± 9.6 min.\(^{-1}\), 88.7 ± 13.81 min.\(^{-1}\)) were similar during both tests (rower vs cycle). Maximal heart rate were significantly higher on the cycle ergometer (177 ± 9 beats / min.\(^{-1}\)) compared to the rowing ergometer (173 ± 11 beats / min.\(^{-1}\)), while the peak power on the rowing ergometer (175 ± 22 watts) was lower than the cycle ergometer (187 ± 41 watts). Blood lactate levels taken one minute following exercise were similar on the rowing ergometer (10.5 ± 1.7 min.\(^{-1}\)) and cycle ergometer (11.8 ± 1.5 m & min.\(^{-1}\)) and indicated maximal effort was achieved in all subjects. Ventilatory threshold levels were significantly different on the rower (2.0 ± 0.16) versus the cycle ergometer (1.9 ± 0.18) (p = 0.38). These data suggest that the cycle and rowing ergometers yield
relatively similar results when testing maximal exercise performance in this population.

Hassmen (1990) conducted a study to find the effect of specialized training upon both physiological performance and perceptual responses. To study this, four groups (with six individuals each) served as subjects. Two of these consisted of highly specialized individuals (racing cyclist and marathon runners) and the other two of non-specialized individuals. Cycling on a cycle ergometer and running on a treadmill were chosen as modes of exercise. Variables measured included heart rate, blood lactate and perceived exertion, rated on two different scales. Result shows a linear increase of both heart rate and perceived exertion in all four groups, although at different absolute level. Blood lactate accumulation during cycling and running, differentiates very clearly between the groups. When heart rate and perceived exertion were allotted against each other, the difference at the same subjective rating between cycling and running amounted to 15-20 beats.min\(^{-1}\) in the non-specialized groups. The cyclists exhibited almost no difference at all as compared to 40 beats min\(^{-1}\) for the runners. It can be concluded that specialized training changes both the physiological as well as the psychological response to exercise.

Lucia et al. (1999) attempted to investigate the breathing patterns of professional cyclist during incremental exercise from sub-maximal to maximal intensities. A group of 11 elite amateur male road cyclist [E mean age 23 (SD2) ] years, peak O\(_2\) uptake [ (VO\(_2\) peak) 73.8 (SD5.0) m/kg (-1) min\(^{-1}\)] and 14 professional male road cyclist [(p, mean age 26 SD2) years (VO\(_2\) peak) 73.2
(SD 6.0) m/kg(-1)·min") participated in this study. Each of the subjects performed an exercise test on a cycle ergometer following a ramp protocol (exercise increases of 25 x min") until the subject was exhausted. For each subject, the following parameters were recorded during the tests. Oxygen consumption (VO2), carbon dioxide output (VCO2), pulmonary ventilation (VE), tidal volume (VT), breathing frequency (fb), ventilatory equivalents for oxygen [VE X VO2 (-1)] and carbon dioxide [VE X VCO2 (-1)], and tidal partial pressure of oxygen and partial pressure of carbon dioxide, inspiratory (tl) and expiratory (tE) times inspiratory duty cycle (tl/TOT, where tTOT is the time for one respiratory cycle), and mean inspiratory flow rate VT/tl). Mean values of VE were significantly higher in E at 300, 350 and 400 W (P>0.05; P<0.05 and P<0.01, respectively), fb was also higher in E in most moderate to maximal intensities. On the other hand, VT showed a different pattern both groups at near – to maximal intensities, since no plateau was observed in P. the response of tl and tE was also different.

Finally VT / tl and tl/tTOT showed a similar response in both P and E. it was concluded that the breathing pattern of the two groups different mainly in two aspects in the professional cyclist. VE increased at any exercise intensity as a result of increase in both VT and fb, with no evidence of tachypnoeic shift, and tE was prolonged in this group at high exercise intensities. In contrast, neither the central drive nor the timing component of respiration seems to have been significantly altered by the training demands of professional cycling.
Rice *et al.* (1999) conducted a study on a group of 15 competitive cyclist [mean peak oxygen uptake VO₂ peak 68.5 SEM1.5Ml x kg⁻¹ x min⁻¹] exercised on a cycle ergometer in a protocol which began at an intensity of 150 W and was increased by 25 W every 2 min. until the subject was exhausted. Blood samples taken from the radial artery at the end of exercise intensity to determine the partial pressures of blood gases and oxyhaemoglobin saturation (sao2) with all values corrected for rectal temperature. The sao2 was also mentioned continuously by ear oximetry. A significant decrease in the partial pressure of oxygen in arterial blood (pao2) was seen at the first exercise intensity(150W, about 40% VO₂ peak). A further significant decrease in pao2 occurred at 200 W. Where after, it remained stable but still significantly below the values at rest, with lowest value being measured at 350w(87CSEM1.9 mm/Hg). The partial pressure of carbon dioxide in arterial blood (paco2) was unchanged up to an exercise intensity of 250w where after it exhibited a significant downward trend to reach its lowest value at an exercise intensity of 375w (34.5 SEM 0.5) mm Hg). During both the first (150W) and final exercise intensities (VO₂ peak)pao2 was correlated significantly with both partial pressure of oxygen in alveolar gas [p(A)O₂,r=0.81 and r=0.70 , respectively] the alveolar arterial difference in oxygen partial pressure (p(a-)02 r=0.63ane r=0.86,respectively) but not with paco2.s

At VO₂ peak P O₂ was significantly correlated with the ventilatory equivalents for both oxygen uptake and carbon dioxide output ( r = 0.58 and r = 0.53, respectively). When both P(A)O₂ and P(A-a) were combined in a multiple linear regression model, at least 95% the variance in pao2 could be
explained at both 150 ward VO$_2$ peak. A significant downward trend in sao2 was seen with increasing exercise intensity with lowest value at 375 W [94.6 (SEM)0.3%]. Oximetry estimated of SaO2 were significantly higher than blood measurements at all times throughout the exercise no significant decrease from rest was seen until 350 W. The significant correlations between pao2 and P(A)O$_2$ with first exercise intensity and at VO$_2$ peak led to the conclusion that inadequate hyperventilation is a major contributor to exercise induced hypoxaemia.

Pels et al. (1987) conducted a study on six males and seven females trained 3 days per wk (30 min. at 80 to 85 % heart rate) for 20 wk on a leg press apparatus. A progressive exercise test was administered on a cycle ergometer, leg press apparatus, and treadmill before and after training. Before training peak oxygen consumption (VO$_2$ Max l kg +/− min.1) during leg press test was higher for males.(23.9 +/- 1.60 mean +/- SE) compared to females (19.5 +/- 2.40,P<0.05). peak VO$_2$ during the cycling (males=36.6 +/- 2,65 females =28.5 +/- 2,35) and treadmill (Males= 39.8 +/- 2.04,females =33.2 +/- 2.64) test was also different between the sexes , and 30 to 40 %. Higher than during the leg press (P<0.05).peak heart rate was not different between the sexes (P<0.05),yet was 11 % lower during the leg press test (165 +/- 3.5) compared to cycling (184 +/- 2.8)and treadmill (187 +/- 1.3) test (P<0.05). After training Peak VO$_2$ during the cycling and treadmill test increased 10 to 15 % , compared to 35 % during the leg press test (P<0.05). The only change in peak heart rate was a 6% increase during the leg press test (P<0.05). Although peak VO$_2$ on the leg press apparatus was lower than
the cycle ergometer and treadmill, leg press exercise elicited a sufficient stimulus for increasing peak VO$_2$ on the three testing modes.

According to Larson et al. (1999), in patients with chronic obstructive pulmonary disease (COPD) in the intensity of aerobic training by is limited by dyspnoea. Improving strength of the inspiratory muscles could enhance aerobic exercise related dyspnoea. They examined effects of home based inspiratory muscle training (IMT) and cycle ergometry training (CET) in 53 patients with moderate to severe COPD FEV(1)% pred, 50 +/- 17 [mean +/- SD]. Patients were randomly assigned to 4 month training in one of four groups: IMT, CET, CET + IMT, or health education (ED). Patients were encouraged to train to the limits of their dyspnoea. Inspiratory muscle strength and endurance increased in IMT and CET + IMT groups compared with CET and ED groups (P<0.01). Peak oxygen uptake increased and heart rate, minute ventilation dyspnoea, and leg fatigue decreased at sub maximal work rates in the CET and CET + IMT groups compared with the IMT and ED groups (P<0.01). There were no differences between the CET and CET + IMT groups. Home based CET produced a physiological training effect and reduced exercise related symptoms while IMT increased respiratory muscle strength and endurance. The combination of CET and IMT did not produce additional benefit in exercise performance and exercise related symptoms. This is the first study to demonstrate a physiological training effect with home-based exercise training.
Fernhall, et al. (1990) conducted a study to investigate the effect of training specificity during maximal and sub maximal treadmill (TM) and bicycle ergometer (BE) exercise. A group of trained runners (RG N0>7) and trained bikers (BG N0.7) underwent graded exercise testing on both TM and BE, utilizing the same testing protocol within each exercise mode for both groups. Data for VO₂, HR and BP were collected during each 3 min. stage. Group by trial ANOVAs followed by Turkey's post hoc analysis, showed no group difference in VO₂ Max, HR max or BP max during TM exercise. However, during each of the first four sub maximal 3 min. stages, VO₂ and HR were significantly less (P<.05) in RG Vs BC, with no significant difference in BP. During BE exercise, VO₂ Max was significant less for both groups compared with TM (RG-59.5 Vs. 50.1 ml.kg⁻¹ min⁻¹ BS-59.4 Vs 55.1 ml.kg⁻¹ MH) (P<0.5), with BG exhibiting the greater BE max (P<0.05). R.G also had a reduced HR as during BE exercise (pv.005). Both groups showed greater BP max during BE Vs. TM exercise (P<0.05). Although sub maximal VO₂ was slightly less during BE for each stage in RG than B.G. these difference were not significant measured either by ml.kg⁻1min⁻¹ or min⁻¹. Both sub-maximal HR and BP mirrored the VO₂ response, with no significant differences between RG and BG. These data agree with previous studies, showing a greater effect of training specificity during maximal BE than during maximal TM exercise. However, during sub maximal exercise, training specificity appear to have a greater effect during TM than BE exercise.
Mier et al. (1997) hypothesized that 10 days of training would enhance cardiac output (CO) and stroke volume (SV) during peak exercise and increase the isotropic response to beta adrenergic stimulation. Ten subjects (age 26+/−2 years) trained on a cycle ergometer 10 days. At peak exercise, training increased O2 uptake, CO and SV (P = 0.001). Left Venticular (LV) size and function at rest were assessed with two dimensional echocardiography before and after atropine injection (1.0 mg) and during four graded doses of dobutamine. LV end-diastolic diameter increased with training (P < 0.02), whereas LV wall thickness was unchanged. LV contractile performance was assessed by relating fractional shortening (FS) to estimated end-systolic wall stress (Sigma ES). Training increased the slope of the FS-sigma ES relationship (P < 0.05), indicating enhanced systolic function. The increase in slope correlated with increases in CO(r = 0.71, P < 0.05) and SV (r = 0.70, P < 0.05). The increase blood volume also correlated with increases in CO(r = 0.80, P < 0.01) and SV( r = 0.85, p < 0.004). These data show that 10 days of training enhance the isotropic response to beta-adrenergic stimulation, associated with increase in CO and SV during peak exercise.

Ruby et al. (1996) conducted a study on cross training response between running and cycling in untrained females.

The study involved a pre test; post test, 3 x 3 factorial design. Training (4 days – week – 10 weeks, 70 – 80 % heart rate reserve). Subjects included healthily, untrained females aged 18 – 25 years ( N = 18).
Subjects were assigned to one of three (n = 6) training groups (run = R, cycle = C, both run and cycle = RC) matched on pre-training CE VO₂ Max results.

Graded treadmill run (TR) and cycle ergometer (CE) tests were performed on each subject to determine a mode specific VO₂ Max and the lactate threshold (LT). Graded arm ergometer (AE) was performed to determine VO₂ Max heart rate and blood lactate at 20 and 40 Watts (W). Testing occurred prior to (OT) after 5 (5T) and after 10 week of training (10T). Body fat testing was performed at OT and 10T.

TR and CE VO₂ Max as well as TR and CE VO₂ at the LT improved throughout the 10 weeks, regardless of training group. Although there were no changes in VO₂ Max or blood lactate levels during AE, sub maximal heart rates were significantly reduced over 10 week, regardless of training group.

These results indicate that the aerobic benefits of either runs, cycle or combined run and cycle training are similar in untrained females. The LT AE heart rate data demonstrate that improvements in VO₂ Max due to ten weeks of training are a result of pronounced peripheral and moderate central adaptations.

Spina et al. (1996) conducted a study to reevaluate the effect of short term training [7 – 10 days] on mitochondrial enzymes in skeletal muscle of humans. Twelve subjects [6 men and 6 women] aged 27 +/- 5 years underwent 7 (n = 5) or 10 days (n = 7) of cycle ergometer exercise for 2 h/day at 60 – 70 % of peak O₂ consumption. Peak O₂ consumption was increased by 9% (from 2.97 +/- 0.16 to 3.14 +/- 0.17 l min.⁻¹) in response to training. Blood lactate levels were
lower at the same absolute work rates after than before training. The activities of citrate synthase, beta-hydroxyacyl-CoA dehydrogenase, mitrochrontrail thiolase, and carnitine acetyleranferase were increased approximately 30% in response to training. The results of this study provide evidence that in humans, as in rats, the adaptive increase in mitochondrial enzymes in skeletal muscle occurs fairly rapidly in response to exercise training. They provide no support for the claim that this adaptive response is delayed for 2 weeks after the on one set of training.

According to Wittels. et al. (1995), recent studies have provided evidence of importance of aerobic endurance training as an independent factor with regard to reducing morbidity and mortality from cardiovascular diseases. Clinical routine shows that test methods and training recommendations are often not specific enough for efficient yet safe exercise. Software is presented which allows cycle ergometry to be used according to the standard criteria in clinical practice, with special attention to the requirements for training with health benefit. Technical requirements: (1) Cycle ergometer with the possibility of increasing exercise intensity by Watt (w) increments. (2) ECG or other device for accurate pulse monitoring (3) IBM - compatible pc and printer. Based upon the input of data on birth date, sex, height, weight and heart rate (HR) at rest the programme calculates body surface area, the reference value of physical work capacity of matching subjects and expected maximal HR (HR max exp) and HR max, exp x 0.95. After the test, input of the HR at exhaustion (HR max), maximum achieved W - increment and time cycled at this intensity in seconds provides various parameters of the individual work capacity. The maximal work performance W
W max) was calculated. This value was used to provide further calculations of W
\( \text{max Kg}^{-1} \), \( \text{VO}_2\text{Max, kg}^{-1} \) and the maximal work performance as a percentage of
normal value (LF%). The software provides an individual training plan with
incremental extension of training time and a prescription for heart rate controlled
intensity of endurance training based upon medically accepted training principles.
The software enables a standard test to be used and recommends medically
efficient and secure quality and quantity guidelines for endurance training.

Hendriksen et al. (2000) conducted a study to determine the effect of
commuter cycling on physical performance. Eighty-seven male and 35 female
employee volunteers cycle regularly to their work. Sixty one participations went
commuter cycling for one year (cycling group) the others cycled only in the
second half of the year (control group). A maximal exercise test on a cycle
ergometer was carried out at the start of the study, after six months, and after one
year to measure maximal external power (W. max) and maximal oxygen uptake
(VO\(_2\)Max).

After six months commuter cycling, with a mean single trip distance
of 8.5 km and a mean frequency of more than three times a week, a significant
increase of 13% was found in the Wmax per kilogram body weight \([\text{Wmax x kg} (-1)]\) in both sexes of cycling group. The improvement in VO\(_2\) Max x kg (-1) was
significant for the male participants (6%) but not for the female participants (-2%).
At the end of the second half year, the control group also showed mean gain in
Wmax x kg (-1) of 13%. Their VO\(_2\) Max x kg (-1) declined in the first half-year, but this was concentrated in the second half year. A dose response relationship
was found between two independent variables and the physical performance, the lower the physical performance at their start of the study and the higher the total amount of kilometers cycled, the higher gain in $W_{\text{max}}$. For subjects with a low initial fitness level, a signal trip distance of only 3 km turned out to be enough to improve physical performance.

Commuter cycling can yield much the same improvement in physical performance as specific training programs.

Kawada et al. (1996) conducted a study to investigate during exercise training; precise control of exercise intensity would maximize the training efficiency while minimizing risks. To adjust work rate, heart rate (HR) has been used as a measure of exercise intensity. Thus they developed a servo controller of the H.R using a cycle ergometer. After estimating the transfer function from work rate to HR, they optimized feedback parameters for achieving a quick and stable HR response by means of a computer stimulation. They then examined the performance of servo controller of HR in 55 healthy volunteers. They set the target HR at 60% and 75% of the age predicted maximum HR. Times required for HR to reach 90% of the target HR were 136±33 and 137 ± 22 sec in the respective protocols. Standard deviations of the steady state difference between the target and measured HRs were 2.5 ±0.6 and 3.8 ±1.1 beats /min. They concluded that the developed servo controller makes it possible to precisely regulate HR and thereby exercise intensity.
Hofmann et al. (1997) conducted a study on heart rate performance curve during incremental cycle ergometer exercise in healthy young male subjects. In 1992 Conconi et al. presented an indirect and noninvasive method for the determination of anaerobic threshold (ANT) in an incremental field test for runners. This noninvasive method for the determination of anaerobic threshold is dependent on the occurrence of the deflection of the heart rate performance curve (HRPC). The aim of this study was to evaluate the degree and direction of the deflection of the HRPC and the relationship of heart rate threshold (HRT) to lactate turn point in a group of 227 healthy young subjects (age 23 ± 4 years). The subjects were divided into three groups by means of second degree polynomial fitting (G1: regular deflection, KHR>0.1; G II no deflection 0<KHR<0.1; G III inverse deflection (<0.1). No significant difference between the groups were found in the anthropometric data or in the power output and blood lactate concentration at both the first (LPT 1) and second (LPT 2) lactate turn points (LPTs) and at maximum performance (P mark). Using the method of Conconi et al. (20), 85.9% of the subjects showed a "regular" deflection, 6.2% showed no deflection at all, and 79% showed even an inverted deflection of the HRPC. An HRT could be obtained in both G I and G II and power output at HRT was not significantly different in comparison to that at the LTP 2. No HRT could be assessed in G II. The heart rate at the HRT and the LTP 2 were significantly lower in G III compared with G I. The phenomenal heart rate break point may be attractive in training regulation but its application is limited because a heart rate deflection cannot be found even in young subjects in some cases.
Mohr et al. (1997) examined the effect of cycle ergometer training on spinal cord injured individuals. Ten such individuals aged 27 - 45 were exercise trained for one year using an electrically individual computerized feedback controlled cycle ergometer. They trained for up-to three times a week (mean 2 - 3 times), 30 min. on each occasion. The gluteal, hamstring and quadriceps were stimulated via electrodes placed on the skin over their motor points. A majority of them were capable of performing 30 min. of exercise in the first bout, however, two individual were only able to perform a few minutes of exercise. After training for one year all the subjects were able to perform 30 minute of continuous training and work output had increased from 4+/-.1(mean +/- SE)to 17+/-.2 kilo Joules per training bout(p<0.05). The maximal oxygen uptake during electrically included exercise increased from 1.20+/-0.08 l per minute measured after a few weeks habituation in the exercise to 1.43 +/- 0.09 l per minute after training for one year PZ 0.05). It is concluded that activity associated changes in exercise performance capacity and skeletal muscle occurring in SCI individuals after injury are reversible even up to over 20 years after the injury. It follows that electrically include exercise training of paralysed limbs is an effective rehabilitation tool that should be offered to SCI individual in the future.

Keyser et al. (1993) conducted a study to determine the effect of an exercise regimen composed of three to six minute intervals of alternating arm and leg cycling on (cross training) on anaerobic threshold (AT) in thirteen men (age = 66 +/- 9, weight = 81 +/- 13 Kg) and two women (age = 58 +/- 21, weight 70 +/- 3 Kg) with coronary heart disease (CHD). The patients cross-trained for
total of 30 minutes per session, three days per week. Maximal cycle ergometer tests with breath-by-breath ventilatory gas analysis were performed before and after training. Peak oxygen uptake increased by 8.9 and peak power output increased ($p < .05$) by 9.6% as a result of the cross-training regimen. Cross training did not effect a significant change in AT but HR at AT was decreased by 6.3% ($p < .05$). Arm and leg cross training produced a physiological adaptation and may have reduced the HR threshold for effective exercise training.

Yamaji et al. (1992) conducted a study to test the ability to perceive exercise heart rate before and after training in six young male university students, perceptions of heart rate being compared with ECG monitored heart rate during cycle ergometry, treadmill running and stair climbing. Between initial and final tests subjects undertook 13 weeks of running training (2h/day, 3-4 days/week) and during this period they compared their perception of heart rate with values observed on watch type wrist mounted pulse monitors. Individual initial perceptions showed only a moderate correlation with ECG values. The correspondence was improved as perceptions were compared with measured heart rates over the course of training significantly so for the mode of exercise most similar to that adopted in the training session (Treadmill running at a heart of 140 beats/min.$^{-1}$). The final accuracy of perceptions at a heart rate of 140 beat/min.$^{-1}$ (error 8-9 beats/min.$^{-1}$ during treadmill running) compared favorably with the accuracy of either pulse counting or the traditional rating of perceived exertion of commonly observed in the exercising public. This suggests that there may be an
application for perceived heart rates in regulating the intensity of prescribed exercise.

Van Ingen Schenau et al. (1992) conducted a study on seven female and eight male elite junior skaters who performed cycle ergometer tests at four different times. The test consisted of a Wingate-type 30.5 sprint test and a 2.5 min. supramaximal test. The subjects were tested in February, May, September and January. Maximal oxygen consumption (VO₂) was measured during the 2.5 min. test. With the exception of the maximal oxygen consumption of the women in May which was about 6% lower than in other three tests, no seasonal changes in the test results could be observed, in spite of a distinct increase in training volume (from 10 to more than 20 hr/week) and training intensity in the course of the season. When the test data were compared to those of elite senior skaters, it appeared that the junior skaters showed same values for mean power output during the sprint test [14.2 SD 0.4] W. Kg for men and 12.6 (SD 0.5) W. Kg⁻¹ for the women] and maximal oxygen consumption [63.1 (SD 2.8)] ml. Kg⁻¹ min.⁻¹ for men and 55.3 (SD 35) ml. Kg min.⁻¹ for women, respectively) as found for senior skaters. It seemed therefore, that the effects of training in these skaters had already leveled off in the period before they participated in this investigation. In contrast to previous studies, no relationship could be shown between the test results and skating performance. This was most likely due to the homogenous character of the groups (mean standard deviation in power and oxygen consumption were only 5%).
Bunc et al. (1994) conducted a study to assess the effects of increasing specific (paddling ergometer) and non specific (cycle ergometer) exercise on parameters relating to the ventilatory threshold (the vent) and work efficiency in 11 young female flat water kayakers. When this trained subjects were tested using non specific work loads, their oxygen uptake (VO₂) values at th(vent), as a percentage of VO₂ Max%(% VO₂ Max) were close to those of untrained subjects [74.2(5.6)% VO₂ Max, mean (SD)]. However, when they tested the same subjects using specific exercise they recorded values typical of highly trained athletes [84.8 (4.7. VO₂ Max%)] For non-specific exercise on the cycle ergometer they recorded work efficiency values close to these of cent trained subjects [22.3(25%)] however, for specific exercise on the paddling ergometer they recorded much lower values [13.4(13.0%)]both at the level of TR(vent). The work efficiency at two warm-up sub-maximal exercise loads on the paddling ergometer was non significantly lower than values on Th vent [12.3(2.8% and (12.9%) (2.9) respectively]. Significant correlations were found between maximal performance VO₂ ml kg⁻¹min⁻¹ and Th vent during paddling and race performance (0.623,0.630 and 0.648 respectively all p<005). Because the results of both specific and non specific sub maximal exercise test are different, they suggest caution in the interpretation of physiological variables that may be sensitive to training status . The evaluation of Th vent and work efficiency as supplementary parameters during laboratory studies enable the determination of the effectiveness of the training process and the specific adaptation of the subjects.
Dregger et al. (1999) conducted a study to investigate a protocol for the determination of VO$_2$ Max utilizing a motor driven skate Treadmill (ST). On separate days, 6 male hockey players completed a ST and cycle ergometer (BK) VO$_2$ Max protocol. The result showed no significant difference between the ST and BK protocols for relative (60.4 +/- 5.09 Vs 59.0 +/- 8.31 ml.kg$^{-1}$min.$^{-1}$) and absolute VO$_2$ Max values (4.51 +/- 0.50 vs. 4.39 +/- 0.59 L.min.$^{-1}$), respectively. Significant higher HR max was recorded during the ST protocol (202.3 +/- 4.27 Vs. 200.7 +/- 4.55 b min.$^{-1}$) (P<0.05). Peak VE and VT were non significant between the two conditions. However, peak f was higher for the ST protocol (63.0 +/- 7.56 Vs. 60.2 +/- 7.76 breath min.$^{-1}$) (P<0.05). Although the physiological response to both protocols was similar, the ST protocol replicates a hockey stride, which may provide more applicable information for the development of training programs.

Stewart et al. (1990) conducted a study to investigate the effects of phosphate loading on VO$_2$ Max in Eight trained cyclist who underwent three cycle ergometer tests (control, placebo, and experimental) to determine whether phosphate ingestion had any positive effect on VO$_2$ Max time to exhaustion, serum 2,3 – DPG, and serum phosphate levels. They found no change between the control, placebo, or experimental conditions in pretest serum phosphate levels, but they did find increases in 2,3 DPG levels in the phosphate condition (P<0.05), which suggests that even a small amount of phosphate could increase levels (P<0.05) and placebo (P<0.02) conditions and also in time to exhaustion between the conditions (P<0.05). They suggest that phosphate may have an ergogenic
effect, but clearly more work needs to be undertaken to ascertain the amount of
phosphate required and the magnitude of the effect.

Cunnigham et al. (1990) conducted a study on three factors related to
exercise with an exercycle, a Motor driven upper and lower body exercise
machine. They examined the effects of exercycle training on peak oxygen
consumption and peak heart rate, peak minute ventilation and peak exchange
ratio. They compared the physiologic responses to graded exercise between
exercycle and a standard lower extremity (LE) cycle Ergometer. They also
compared the difference in training responses between male and female subjects.
A 6 week cardio respiratory training program was completed by 20 healthy
untrained adults (9 male, 11 female), aged 18 to 53 years. Pre training and post
training testing was completed on the exercycle and on an LE cycle ergometer
using a graded protocol. Absolute peak VO₂ improved by 14% for men and 7%
for women after training based on exercycle testing and by 6% for both men and
women based on LE cycle ergometer testing. The post training submaximal heart
rates were lower at any given absolute peak VO₂ level for the exercycle but not for
the LE cycle ergometer testing for both genders. The exercycle peak VO₂ than did
LE cycle ergometer testing for both genders. The exercycle appears to be effective
for promoting cardio respiratory fitness in healthy, untrained adults. The authors
found comparably sub maximal physiologic responses to graded exercise between
the exercycle and the LE cycle ergometer.
2.2. STUDIES ON KINANTHROPOMETRIC AND PERFORMANCE VARIABLES

Martin et al. (1990) conducted a study on continuous assistive – passive exercise (CAPE) is a new exercise Modality that has become popular in older females. To evaluate the efficacy of CAPE, 43 sedentary post-menopausal women (PMW) were randomly divided into three groups: CAPE training (N=15), cycle ergometer training (N=14), and control groups (N=14). The CAPE training consisting of 10 min. bout on six CAPE tables twice per week. The cycle ergometer group was trained twice per week for 30 minutes per session, at 70-85% of maximal heart rate. The cycle ergometer and CAPE groups trained for 12 weeks while the control group remained sedentary for duration of the study. Groups were similar with respect to age, height, weight, girths, skinfolds, and aerobic power, VO₂ Max, upon entering the study (P>0.05). The groups were tested pre and post – training on the sum of seven body girths (Sigma 7G), sum of four skinfolds (Sigma 4SF), weight, and VO₂ Max. A 3 dietary recall was recorded pre and post and analyzed for total caloric intake. Following training, changes in caloric intake, sigma 7G, and Sigma 4SF were not significantly different among groups. The cycle group lost .1 kg (P<0.05) and increases VO₂ Max (1.min.-1) by 9.2% (P<0.05), while the CAPE group significantly decreased VO₂ Max (P=0.04). Results indicate that CAPE does not alter Sigma 7G or Sigma 4SF in sedentary PMW and that two 30 min. sessions of cycle training per week at 70-85% of maximal heart rate can result in moderate but significant increase in VO₂ Max in sedentary PMW.
Schuit et al. (1998) conducted a study to find out the effect of a six-month training program on changes in body weight and lipid concentrations, and their inter relationship in elderly people. Intervention study. The elderly subjects were randomly assigned to a control group or one of two supervised aerobic training groups either all round activities or ergometer cycling, both exercising 3-4 times a week for six months. 229 elderly men and women aged 60 to 80 years were served as subjects. Various fatness parameters by anthropometrics, serum lipids and peak power output were measured.

During the intervention, no significant changes were observed in weight of body fatness in subjects of training groups. Serum high density lipoprotein (HDL), low density leprosies (LPL), and total cholesterol and triglycerides tended to change in a favorable direction in the elderly of the intervention group, but only triglyceride concentration in women of the cycle ergometer group and total serum cholesterol and HDL cholesterol concentrations in subjects of the all round activity group, were significantly reduced as compared to control group. Regression analysis showed that the intervention control difference in change of all lipids was independent of changes in weight, body fat and previous engagement in sport activity.

Regular physical exercise in an elderly population resulted in favorable changes in serum lipid concentrations that were not significant, but no change in body weight or fatness. Change in lipid concentration could not be attributed to change in weight or body fat.
Kreider et al. (1998) conducted a study to determine the effects of 28 days and of creatine supplementation during training on body composition.

In a double blind and randomized manner 25 NCAA division I-A football players were matched paired and assigned to supplement their diet for 28 days and during resistance / agility training. Before and after supplementation, fasting blood samples were obtained total body weight, total body water, body composition were determined; subjects performed a maximal repetition test on the isotonic bench press, squat, and power clean; and subjects performed a cycle ergometer sprint test (12x6.se sprint with 30.se rest recovery).

Hematological parameters remained within normal clinical limits for active individual with no side effects reported. Total body weight significantly increased (PLOOS) in the HP group (P.0.85+/-2.2;HP2.42+/-1.4kg) while no differences were observed in the percentage of total body water. DEXA scanned body mass (P 0.77+/-1.8;HP2.27+/-1.5 and fat/bone free mass (P 1.33+/-1.1HP;2.43+/-1.4kg were significantly increased in the HP group. Gains in bench press lifting volume (P-5+/-134;HP225+/-246kg), the sum of bench press, squat, and power clean lifting volume (P 1,105 +/- 429;HP1,558+/-645kg), and total work performed during the first five 6 seconds sprint was significantly greater in the HP group.

The addition of creatine to the glucose / taurine / electrolyte supplement promoted greater gains in fat/bone free mass, isotonic lifting volume, and sprint performance during intense resistance / agility training.
Almuzaini, *et al.* (1998) conducted a study on how splitting a 30 min. exercise bout on a cycle ergometer into two equal sessions affects excess post exercise oxygen consumption (EPOC) and resting metabolic rate (RMR). In this study, 10 male volunteers (age 23 +/- 3.8) participated in two exercise trials, which were randomly assigned in a counter balanced design and separated by a 40 hr. One trial was 30 min. of exercise at 70% VO\textsubscript{2} Max (CONT), followed by a 40 min. measurement of EPOC. The second trial was divided into 15 min. sessions (SPLIT), separated by 6 hour. A 20 min. measurement of EPOC followed each SPLIT session. Results indicated that the combined magnitude of EPOCs from SPLIT (7,410 +/- 1,851 ml) was significantly greater than that from CONT (5,278 +/- 1,305 ml). Data indicate that dividing a 30 min. exercise session into two parts for these individuals significantly increases magnitude of EPOC but does not affect RMR.

Linossier *et al.* (1997) investigated the effect of sprint training and detraining on sub maximal performances in relation to muscle enzyme adaptations in eight trained athletes four times a week for 9 weeks on a bicycle ergometer. The subjects were tested for peak (VO\textsubscript{2} peek) oxygen uptakes, maximal aerobic power (MAP) and maximal short term power output (Wmax) before and after training and after 7 weeks of detraining. During these periods, biopsies were taken from vastus laceralis muscle for the determination of creatine kinase (CK) adenylate kinase (AK) glycogen phosphorylase (PHOS), hexokinase (HK) phosphofructokinase (PFK) lactate dehydrogenase (LDH) hexokinase (HK) and its lysozymes, 3-hydroxy-acyl-coA dehydrogenises (HAD) and citrate synthase
(CS) activities. Training induced large improvements in W max (28%) with slight increases (3%) in VO$_2$ peak (p < 0.10). This was associated with a greater glycoltic potential as shown by higher activities for PHOS(9.1) PFK (17.1) and LDH(31%) after training, without changes in CK and oxidative markers (CS and HAD). Detraining induced significant decrease in VO$_2$ peak (4%) HAP(5%) and oxidative markers (10 – 16%). This suggests a high level in supramaximal power output as a result of a muscle glycogenolytic and glycolytic adaptation. A long interruption to training has negligible effects on short sprint ability and muscle anaerobic potential. On the other hand a persistent training stimulus is required to maintain high aerobic capacity and muscle oxidative potential. This may contribute to a rapid return to competitive fitness for sprinters and power athletes.

Gastin et al. (1994) conducted a study to find out the influence of training status on the maximal accumulated oxygen deficit (MAOD) during supramaximal all out cycle exercise. Sprint trained (ST; n = 6) endurance trained (ET; n = 8) and active untrained controls (UT; n = 8) completed a 90 sec. all out variable resistance test on a modified monark cycle ergometer. Pretest included the determination of peak oxygen uptake (VO$_2$ peak) and a series (5 – 8) of 5 min. discontinuous rides at sub maximal exercise intensities. The regression of steady state of oxygen uptake on power output to establish individual efficiency relationships was extrapolated to determine the theoretical oxygen cost of the supramaximal power output and achieved in the 90 sec all-out test. Total workout put in 90 sec was significantly greater in the trained groups (p < 0.05), although no differences existed between ET and ST. Anaerobic capacity, as assessed by
MAOD, was larger in ST compared to ET and UT. While the relative contributions of the aerobic and anaerobic energy systems were not significantly different among the groups, while ST were able to achieve significantly more anaerobic work. Peak power and peak pedaling rate were significantly higher in ST. The results suggested that MAOD determined during all-out exercise was sensitive to training status and provided a useful assessment of anaerobic capacity.

In this study sprint training compared with endurance training, appeared to enhance significantly proper output and high intensity performance over brief periods (up to 60 sec) yet few over all differences in performance (i.e. total work) existed during 90 sec of all-out exercise.

Linossier, et al. (1993) examined the effect of 7 week of sprint training on maximal power output (WV, max) determined during a force-velocity test and 30 sec for Wingate test(W peak); in ten students (22 (SD2) years) exercising on a cycle ergometer. Before and after training, muscle biopsies were taken form Vastus lateralis muscle at rest for the ten subjects and immediately after a training session for five of them. Sprint training induced an improvement both in peak performances by 25% (Wv, max and W peak) and in the 30-S total work by 16%. Before sprint training, the velocity reached with no load (VO) was related to the resting muscle phosphocreatine (PCR) stores (r=0.87, P<0.001). The training induced changes in VO were observed only when these PCR stores were lowest. This pointed to a possible limiting role of low PCR concentrations in the ability to reach a high velocity. The improvement in performances was linked to an increase in the energy production from, aerobic glycolysis. The result was
suggested in muscle by increase in lactate production measured after a training session associated with the 20% higher activity of both phosphofructokinase and lactate dehydrogenases. The sprint training also increased the proportion of slow twitch fibers closely related to decrease in fast twitch fibres. This result would appear to demonstrate an appropriate adaptive reaction following high-intensity intermittent training for the slow twitch fibres which exhibit a greater oxidative capacity.

Linossier et al. (1997) experimented the ergometric effect of sprint training and detraining in relation two muscle fibre changes in seven student trained during 9 weeks on a cycle ergometer. Before and after training and after 7 weeks detraining they performed a force velocity test on a friction loaded cycle ergometer. On these three occasions muscle samples were taken from vastus lateralis muscles at rest for histochemical analysis. The training induced changes in VO2 Max reached against FBI Wmax (VM) Wmax allowed them to produce evidence for two particular sub groups in which inverse fibre conversions were observed. Sub group A the lowered post training Vm Wmax was associated with a decrease in both FTa and FTb fibre. Conversely the Vm Wmax, increase in subgroup B was associated with a higher percentage FT fibre as the result of increased FT a fibre and decreased FTb fibre. Thus ,the fibre hypertrophy associated with a unidirectional fibre translation [FTb - FTa ]

Slow twitch (ST) fibres with a high thermo dynamic efficiency would result mainly in increased force qualities, were as the bi-directional fibre
translation (ST FTa FTb ) would allow enhancements of both force and velocity properties.

Bentley et al. (2000) conducted a study to assess the effects in trained cyclist of exhausting endurance cycle exercise (CE) on maximal isometric force production, surface Electromyogram (EMG) and activation deficit (AD) of the knee extensor. Ten male subjects made four isometric maximal voluntary contractions (MVC) of knee extensor muscles immediately prior, 10 min. after (post) and 6h after computation of CE. The CE consisted of 3 min. of exercise on a stationary cycle ergometer at an intensity corresponding to 80 % of maximal oxygen uptake (VO2 Max) followed by four x 60 se periods at 120 % of (VO2 Max). Two MVC are performed with the recording of surface EMG from the knee extension whilst an additional two MVC were completed with percutaneous electrical muscle stimulation (EMS, 25 Pulses at 100 HZ with the maximal tolerable current) superimposed over the maximal voluntary contraction force (MVC) but without EMC (to avoid interference). The MVF integrated EMG (1 EMG) and AB calculated as the difference between MVF and electrically stimulated (ES) during EMS contractions were statistically analyzed. The MVF was significantly reduced (p < 0.05) post compared to pre CF level. The EMG was significantly reduced (p < 0.05) post and 6h post CE. The ESF was too reduced, whilst AD was significantly increased (p < 0.05) post and 6 h post CE compared to pre CE. These results suggest that the level of exercise stress administered in this study was sufficient to impair the central peripheral mechanism of force generation in knee extensors for a period of 6 hours. Athletes
engaged in concurrent training (strength and endurance) should consider this effect on exercise programming.

Hauhtier et al. (1996) conducted a study to determine whether power-velocity relationship obtained on a non-isokinetic cycle ergometer could be related to muscle fibre type composition. Ten healthy especially trained subjects (eight men, and two women) performed brief periods of maximal cycling on a friction loaded cycle ergometer. Frictional force and flywheel velocity were recorded at a sampling frequency of 200 hz. power output was computed as the product of velocity and inertial and frictional forces. Force, velocity and power were averaged over each down stroke. Muscle fibre content was determined by biopsy of the vastus lateralis muscle. Maximal down stoke power [14.36 SD 2.37] W.kg-1] and velocity at maximal power [120 (SD8) rpm] were in accordance with previous results obtained on an isokinetic cycle ergometer. The proportion of fast twitch fibers expressed in terms of cross sectional area was related to optimal velocity (r = 0.88, p < 0.001), to squat jump performance (r = 0.78 p < 0.01) and tended to be related to maximal power expressed per kilogram of body mass (r = 0.60, p = 0.06). Squat jump performance was also related to cycling maximal power, expressed per kilogram of body mass (r = 0.87, p < 0.01) and to optimal velocity (r = 0.86, p < 0.01). All these data suggest that the non-isokinetic cycle ergometer is a good tool with which to evaluate the relative contribution of type II fibers to maximal power output. Furthermore, the strong correlation obtained demonstrated that optimal velocity when related to training
status would appear to be the most accurate parameter to explore the fiber composition of the keen extensor muscle.

Mutton et al. (1993) conducted a study to evaluate the effects of 5 wk of equivalent intensity 85-90% maximum heart rate (MHR), runs only (N=6) vs cycle / run (N=5) training in moderately fit runners, mean VO$_2$ Max of 55.2 ml.kg min. ,19-35 years old, on maximal treadmill(TM) and cycle ergometer (CE) testing, 5000m and 1600m run performances and sub maximal measures while treadmill running. Subjects participated in either 4 days / week of run only or alternating run and cycle training. Both groups significantly improved TM VO$_2$ Max (P<0.05), CE VO$_2$ peak (P<0.01) and 5000m (P<0.001) and 1600-m (P<0.05) run times with no significant differences between the groups. The TM VO$_2$ Max pre/post values were 55.3 +/- 3.0 to 58.2 +/- 3.0 and 55.6 +/- 3.8 to 58.9 +/- 2.4 ml kg min.$^{-1}$ for the run group and cross trained group respectively. Post training sub maximal treadmill running showed statistically significant pace increases of 18.7 (run) and 16.1 (cycle/run) min.$^{-1}$ with similar heart rate, blood lactate, and RQ values as pre training. Results indicate that 5 weeks of either mode of training can significantly improve aerobic capacity and run performance.

Gleeson et al. (1995) conducted a study to determine whether Delayed Onset Muscle Soreness (DOMS) inducing exercise affects physiological responses to subsequent sub maximal dynamic exercise. Physiological and metabolic responses to a standardized exercise task were measured two days after the performance of an eccentric or concentric exercise bout. Six healthy, untrained male subjects aged 30 ± 7 years (Mean ± SD) performed repeated eccentric
contractions during 30 minutes of bench stepping (47 cm step; 15 step per min.)

On other occasion, they performed concentric contraction by walking uphill (8% incline) for 30 min. at 5km h⁻¹, which elicited a similar heart rate response to bench stepping. Two days after the eccentric or concentric exercise the subjects cycled for 15 min. on an electrically braked cycle ergometer at a work rate 172 ± 37 W) equivalent to 80% VO₂ Max. They conclude that dynamic sub maximal exercise performed two days following exercise with a large eccentric component produces physiological responses that are indicative of a higher relative exercise stress. It is likely that such effects will significantly limit the level and duration of exercise can be achieved in subsequent training bouts over several days.

Chicharro et al. (1999), conducted a study to compare several metabolic parameters determined at OBLA and at a fixed heart rate of 175 beats X Min.⁻¹ (HR 175) in amateur cyclist (AC) and professional cyclist (PC). Sixteen AC and 22 PC performed an exercise test on a cycle ergometer following a ramp protocol (25 W x Min⁻¹), 70-80 rpm) to exhaustion. Gaseous exchange was monitored throughout the test. VO₂, % VO₂ Max, and power output (W) corresponding to OBLA and HR175 were determined and mean values compared using a students’ t-test. Finding indicated higher VO₂ Max and W in general in PC<0.01), and higher VO₂ Max and W at OBLA and HR175 in PC (P<0.01). No significant differences was found between values determined at OBLA and HR175 in AC group, while in the PC group, VO₂% VO₂ Max, and W were higher at OBLA. These observations suggest the possible use of a fixed, reference HR of
175 beats x min\(^{-1}\) to determine the exercise intensity corresponding to OBLA in amateur cyclist. This was not the case for the professional cyclist.

Vukovich et al. (1997) examined whether amino acid supplementation influences blood and muscle lactate response to exercise and the time course of the metabolic adaptations to training. Two groups of untrained males (\(n = 7\) each) were given (double blind) a daily supplement (2.9 g day\(^{-1}\)) containing a mixture of leucine, isoleucine, valine, glutamine, and carnitine (Exp) or 3g.day\(^{-1}\) of lactose (CON). Following 7 days of supplementation there was no significant change in VO\(_2\) peak, time to exhaustion (TTX) at 120% VO\(_2\) peak, or muscle and blood lactate in either Exp or CON. Subjects then initiated 6 weeks of combined aerobic and anaerobic training on a Monark cycle ergometer. It was found that amino acid supplementation had no effect on either blood or muscle lactate accumulation during exercise, while supplementation resulted in a faster adaptation in buffer capacity. Performance during intense exercise was not improved with amino acid supplementation.

Stockhausen et al. (1997) conducted a study to identify the minimum duration exercise necessary to establish (QSS) (Quasi Steady State) following various increments in WL (10, 20, 30, 40 and 50 W). Eight male endurance trained cyclist performed three different exercise test on a cycle ergometer (1) an exhaustive IT with a starting work load of 100 W, followed by 20-W increments every 3 min. (2) a threshold test with 20 W increments every 9 min. to determine the max LaSS, and (3) five incremental exercise test with a final 10-20-30-40 or 50 W increments lasting 10 min. at 10 w below max LaSS. The time constant lactate
kinetics (tau) the time constant of lactate elimination, and the time taken to elicit QSS defined as 95% of time taken to reach steady state level (+ 95%) were calculated in the T10 – T50 experiments. The tau and + 95% increased significantly with WL increment size: the correlation was not linear. Smaller WL increments required proportionally longer durations. Mean (SD) +95 values (Min. :S) were 1.57 (0.27) T10), 2.58 (0.16, T20), 4.08 (0.23) (T30), 4.45 (0.45) (T40) and 5.06 (0.43) (T50). The applications of these references in IT protocols may lead to an extension of total test duration, particularly with smaller increments. Therefore lactate threshold modelling the training status of the athletes and comparability with lactate measurements obtained during training events should be considered. IT protocols not accomplishing QSS criteria may affect an underestimation of WL – related lactate values and an overestimation of lactate thresholds, Which indicate Max LaSS, especially in highly trained athletes. This suggests that the establishment of an increment-size dependent t 95% may reduce protocol – related influences on AnT and standardize the use of the AnT in IT procedures in the training management of elite cyclist.

Blannin et al. (1996) attempted to investigate the effects of long term (> 10 years) endurance training and sub maximal exercise on the phagocytic activity of circulating neutrophil granulocytes.

The ability of stimulated blood neutrophils isolated from well trained cyclist. [n = 8; VO2 Max 61.0 (SD = 88) m/kg – 1 min⁻¹; age 38(4) years] and age matched sedentary controls [n = 8] VO2 Max 37.4 (6.6) ml.kg⁻¹min⁻¹] to ingest
nitroblue tetrazolium was assessed at rest and following a standardized submaximal bout of exercise on a cycle ergometer.

Trained subjects had a lower resting blood neutrophil count (p < 0.01). Acute exercise caused a rise (p < 0.01) in the blood neutrophil count irrespective of training status, but the magnitude of the rise was smaller in the trained subjects (p < 0.05). The circulating neutrophil phagolytic capacity was approximately 70% lower in trained individuals at rest compared with the control subjects (p < 0.01). Acute sub maximal exercise increased this variable in both groups, but phagocytic capacity remained substantially lower in trained subjects compared with controls (p < 0.05) despite the observation that a higher proportion of the circulating neutrophils were stimulated to undergo phagocytosis in the trained subjects [57 (14) % V 32 (7) %; p < 0.01].

Although neutrophil phagocytic activity is only one variable that contributed to immunological status, prolonged periods of endurance training may lead to increased susceptibility to opportunistic infections by diminishing this activity at rest.

Wanke et al. (1994) conducted a study to determine whether inspiratory muscles training could intensify the known beneficial effects of cycle ergometer training on exercise performance in these patients. They compared the effect of an 8 week inspiratory muscle training combined with cycle ergometer training with that of as 8 week cycle ergometer training alone on inspiratory muscle performance and general exercise capacity. Patients were assigned to the two training groups; 21 patients received additional inspiratory muscle training
(Group 1) and 21 did not (Group 2). Maximum sniff assessed oesophageal and transdiaphragmatic pressures served as parameters for global inspiratory muscle strength and diaphragmatic strength respectively. The duration for which the patient could breath again a constant inspiratory pressure load was used as an index of inspiratory muscles endurance. Exercise capacity was determined by an incremental symptom limited cycle ergometer test. After the training period inspiratory muscle performance improved significantly in the patients with respiratory muscles training, but not in those with out. Both training regimens increased maximal power output and oxygen uptake, but this improvement was significantly greater in the patients with inspiratory muscles training than in those without.

Loy et al. (1994) conducted a study to examine the effect of 12 weeks of stair climbing with and without an external load on aerobic capacity and quadriceps strength of sedentary (initial VO₂ Max 25.3 ± 0.73 mlkg⁻¹/min.) (mean ± SEM), middle aged females (50-65 years). Three groups, LOAD (stair climbing with external load, N=8), STAIR (no load, N=9), and CONTROL (N=7) were tested. By week 4, subjects warmed up 5 min. on a cycle ergometer followed by 35 min. on the stairclimbing at 80-85%. Maximum heart rate (MHR) 4 days per week. In week 6, the LOAD group carried an external load of 4% of body weight increasing to 8% for weeks 7-12. STAIR and LOAD group significantly increased (P<0.01) VO₂ Max by 11.1% and 9% respectively. Isokinetic strength tests showed increased (P<0.05) peak torque and total work for STAIR and LOAD at 120 and 180 degrees S⁻¹. For total work a significant increase (P<0.05) of 10.5% was
observed at 60 degrees S-1 for LOAD group. The results indicate stair climbing is an appropriate exercise for middle aged females improving both aerobic capacity and strength following 12 weeks of training.

Hickey, et al. (1992) conducted a study to assess the reproducibility of laboratory cycling performance. Eight well trained (VO2 Max = 4.6+/0.21 min⁻¹) male cyclist completed 12 trials involving 4 successive performance rides at each of three total work outputs (approximately 1600, 200 and 14 kilojoules). These trials, designated as long medium and short trials (LT, MT, ST,) represented exercise bouts of 105.12+/0.4, 12.03+/0.17 and 0.55+/0.11 minutes. respectively. These trials conducted on a computerised cycle ergometer in an isokinetic mode, were separated by a minimum of 72 hours. All trials for each subject were completed at the same time of day. In all trials, subjects were allowed to select the pace in order to complete the ride in the shortest possible time. The mean coefficient of variation (CV) for performance time in each trial was: LT=+/1.01%, MT=+/0.95% and ST =+/2.43%, respectively. The CV for performance time in ST was significantly greater than CV in either LT or MT. In LT, performance time was significantly faster, and the mean% Vo2 max was significantly higher in trial 4 versus trial 1-3. Then there was no order effect in the MT or ST rides. The CV for mean VO2 (1 min⁻1), Mean% Vo2 max, and RER during the LT rides were +/-3.02%, +/-3.64% and +/-3.53% respectively. These date suggest that trained cyclist have ability to reproduce endurance performance with a CV and approximately 1.0% in a time trial protocol.
Bonzheim et al. (1992) conducted a study to clarify the influence of body position on exercise prescription, 14 men (mean age +/- S.D. 60.0 +/- 6.1 years) with coronary heart disease who underwent randomized recumbent and upright cycle ergometer tests to volitional fatigue were studied. At 100 wats, heart rate (HR) systolic blood pressure, oxygen consumption (VO₂), rate pressure product and rating of perceived exertion were greater (p < 0.05) in the upright than in the recumbent position. At peak exercise, however, these variables were not significantly different. Regressions of relative HR versus VO₂ for recumbent and upright cycle ergometry were comparable Y = 1.24 x = 32.7 and y = 1.26 x = 31.5, respectively, where y = % maximal VO₂ and X = % maximal HR. These findings indicate that recumbent exercise prescriptions may be based on the peak HR and VO₂ values obtained during upright cycle ergometry, and vice versa. However, differences in the cardio respiratory responses at submaximal, exercise preclude the interchangeability of upright and recumbent training work rates.

McManus et al. (1997) investigated the effects of two, three time a week, 8 weeks training programs on the aerobic power and anaerobic performance, of 30 prepubescent girls, with a mean age of 9.6 years: peak oxygen uptake was assessed by an incremental discontinuous treadmill test, and peak power in 5 seconds and mean power over 30 seconds estimated from a wingate anaerobic test were used as the criterion measures, Twelve girls trained using a continuous cycle ergometer program, 11 girls followed a sprits running program and the control group consisted of 7 girls. Both training groups significantly (p<0.05) increased their peak oxygen uptake and peak power in 5 se, However the increase reported here is
lower than those generally observed in adolescents following training. The control group demonstrated no significant (P>0.05) change in either variable. No significant (P>0.05) changes in mean power over 30 sec were observed in any group.

Jenkins et al. (1991) conducted a study to examine the relationship between the y-intercept from the critical power curve and measures of anaerobic work capacity (AWC) gained from repeated maximal exercise. Nine male volunteers of moderately high training status (VO₂ Max 4.45 +/- 0.251/min.) completed three cycle ergometer test to exhaustion (at 300, 350 and 400w) for the determination of CP. A second cycle ergometer task involved repeated maximal effort (against 0.075 N/Kg body mass) over five 1 min. periods. Five minute of passive recovery separated each exercise bout, at the end of which capillary blood was collected for lactate analysis. On completion of the fifth bout, venous blood was sampled for the determination of blood pH. Total accumulated work provided a performance estimate of AWC which, together with blood lactate and pH, was compared to the y-intercept. Correlation analysis revealed a significant relation between the y-intercept and total work accomplished (r=0.74; P<0.05) while the post-exercise venous blood pH was positively related to both the y-intercept (r=0.92, P<0.01) and the accumulated work recorded (r=0.92, p<0.01). No significant correlation between peak blood lactate and work was found, although a relation between post-exercise venous blood pH and VO₂ Max was established (r=0.84; P<0.05). The capacity for high intensity interval work was represented by the y-intercept in active males. Furthermore, the relationship between blood PH and both the y-
interrupt and accumulated work suggest that either improved buffering or a greater contribution of aerobic metabolism to the energy yield may have been responsible for the more successful performance in the interval exercise.

According to Poole et al. (1990), the tolerable work duration (t) for high intensity cycling is well described as a hyperbolic function of power (W);

\[ W = (W_t) + W_a \]

where \( W_a \) is the upper limit for sustainable power, and \( W' \) is a constant which defines the amount of work which can be performed greater than \( W_a \). As training increases the tolerable duration of high intensity cycling, they explored whether this reflected an alteration of \( W_a \), \( W' \) or both. Before and after a 7 week regimen of intense interval cycle training by males, they estimated theta lac and determined maximum \( \text{O}_2 \) uptake (\( W_u \)); \( W_a \); \( W' \); and the temporal profiles of pulmonary gas exchange, blood gas, acid-base and metabolic response to constant load cycling at and above \( W_a \). Although training increased theta lac (24%) \( W_u \) (15%) and \( W_a \) (15%) \( W' \) was unaffected. For exercise at \( W_a \), a steady state was attained for \( \text{VO}_2 \) (lactate) and PH both pre- and post – training, despite blood and rectal temperature continuing to rise. For exercise greater than \( W_a \), there was a progressive increase in \( \text{VO}_2 \) and rectal temperature, and a progressive decrease for PH. They conclude that the increased endurance capacity for high-intensity exercise following training reflects an increased \( W \) asymptote of the \( W.t \) relationship with no effect on its curvature; consequently, there is no appreciable change in the amount of work which can be performed above \( W_a \).
Peronnet et al. (1986) conducted a study on plasma concentration at rest and in response to maximal exercise on the cycle ergometer (278 +/- 15 watts, 6 min.) exercise on seven young active male subjects (19 +/- 1 year (80 +/- 3 kg; 176 +/- 3 cm) prior to and after a eight weeks leg strength training program. Strength training resulted in a significant increase in performance on squat and leg press exercise associated with a small significant increase in lean body mass (LBM) and no change in maximal oxygen consumption. Plasma concentrations were not significantly different before and after training at rest NE: 172 +/- 19 Vs 187 +/- 30; E 33 +/- 10 Vs 76 +/- 16) on in response to maximal exercise (NE: 3976 +/- 660 Vs 4163 +/- 1081; E: 1072 +/- 322 Vs 1321 +/- 508). Plasma lactate concentration during recovery was similar before and after training (147 +/- 5 Vs 147 +/- 15 kg x dl^-1) Under the assumption that the "central command" is reduced for a given absolute workload on the bicycle ergometer following leg strength training, these observations support the hypothesis that the sympathetic response to exercise is under control of information from muscle chemoreceptors.

Baxter et al. (1993) conducted a study on measurement of anaerobic power and capacity in athletic men. These physiological characteristics have been determined predominantly using cycle ergometry and treadmill sprinting. The purpose of their study was to examine the relationship between 40 m maximal shuttle run times and performance indices obtained during treadmill sprinting and cycle ergometry. Moderate correlations were found between 10m split times (the time taken to cover the initial 10 m of shuttle course) and treadmill peak power outputs (r = 0.67; p < 0.05). Similar relationships were also found between
the fastest 40 m time and mean power outputs generated on both the treadmill and cycle ergometer ($r = 0.67; p < 0.05$) and $r = 0.75; p < 0.05$ respectively. The correlations remained unchanged when the values were adjusted for body weight ($w$ kg$^{-1}$). The result of this study suggests that maximal 40-m shuttle running ability may reflect anaerobic indices of power and capacity determined using standard laboratory exercise.

Smith (2000) conducted a study to find out the effects of 3 weeks of a 30% increase in training volume, followed by 1 week of reduced volume (approximately 75%) training, on ergometer sprint performance and physiological recovery responses, were determined from an initial group of ten male and eight female elite rowers. No significant ($p > 0.05$) differences in mean ( +/- SD) 500m time trial performance were found when comparing 500 m times prior to, and after 3 weeks of overload training (89.4 +/- 7.3s vs. 88.1 +/-7.3s), or from the end of the overload training to after the regeneration week (88.6 +/- 6.8 s), or over the full 4-week overload - regeneration cycle. Peak and recovery heart rate responses to the test did not differ with training. However, recovery blood lactate concentrations increased, and blood ammonia deceased after the third and fourth weeks of training. The results indicate that 3 weeks of overload training did not compromise ergometer sprint performance, but altered the metabolic responses during passive recovery. A subsequent 1-week period of 25% reduced volume training was insufficient for positive regenerative adaptations and improved performance.
Rodas et al. (2000) conducted a study to evaluate the changes in aerobic and anaerobic metabolism produced by a newly devised short training programme. Five young male volunteers were trained daily for 2 weeks on a cycle ergometer. Sessions consisted of 15-s all-out repetitions with 45-s rest periods, plus 30-s all-out repetitions with 12-min. rest periods. The number of repetitions was gradually increased up to a maximum of seven. Biopsy samples of the vastus lateralis muscle were taken before and after training. Performance changes were evaluated by two tests, a 30-s all-out test and a maximal progressive test. Significant increases in phosphocreatine (31%) and glycogen (32%) were found at the end of training. In addition, a significant increase was observed in the muscle activity of creatine kinase (44%), phosphofructokinase (106%), lactate dehydrogenase (45%), 3-hydroxy-acyl-CoA dehydrogenase (60%) and citrate synthase (38%). After training, performance of the 30-s all-out test did not increase significantly, while in the maximal progressive test, the maximum oxygen consumption increased from mean (SD) 57.3 (2.6) ml x min.(-1) x kg(-1) to 63.8 (3.0) ml min.(-1) x kg(-1), and the maximum load from 300 (11) W to 330 (21) W; all changes were significant. In conclusion, this new protocol, which utilises short durations, high loads and long recovery periods, seems to be an effective program for improving the enzymatic activities of the energetic pathways in a short period of time.

Parra et al. (2000) conducted a study to find out the effect of the distribution of rest periods on the efficacy of interval sprint training. Ten male subjects, divided at random into two groups, performed distinct incremental sprint
training protocols, in which the muscle load was the same (14 sessions), but the distribution of rest periods was varied. The 'short program' group (SP) trained every day for 2 weeks, while the 'long program' group (LP) trained over a 6-week period with a 2-day rest period following each training session. The volunteers performed a 30-s supramaximal cycling test on a cycle ergometer before and after training. Muscle biopsies were obtained from the vastus lateralis before and after each test to examine metabolites and enzyme activities. Both training programs led to a marked increase (all significant, P < 0.05) in enzymatic activities related to glycolysis (phosphofructokinase - SP 107%, LP 68% and aldolase - SP 46%, LP 28%) and aerobic metabolism (citrate synthase - SP 38%, LP 28.4% and 3-hydroxyacyl-CoA dehydrogenase - SP 60%, LP 38.7%). However, the activity of creatine kinase (44%), pyruvate kinase (35%) and lactate dehydrogenase (45%) rose significantly (P < 0.05) only in SP. At the end of the training programme, SP had suffered a significant decrease in anaerobic ATP consumption per gram muscle (P < 0.05) and glycogen degradation (P < 0.05) during the post-training test, and failed to improve performance. In contrast, LP showed a marked improvement in performance (P < 0.05) although without a significant increase in anaerobic ATP consumption, glycolysis or glycogenolysis rate. These results indicate that high-intensity cycling training in 14 sessions improves enzyme activities of anaerobic and aerobic metabolism. These changes are affected by the distribution of rest periods, hence shorter rest periods produce larger increase in pyruvate kinase, creatine kinase and lactate dehydrogenase. However, performance
did not improve in a short training program that did not include days for recovery, which suggests that muscle fibres suffer fatigue or injury.

2.3 SUMMARY OF REVIEW OF LITERATURE

The relevant literature collected after exhaustive review of the different sources throw ample light with regard to bicycle ergometer training on selected physiological and kinanthropometric, and performance variables. Thus, this chapter describes the review of the related literature; which is essential to interpret the result to support the present problem. More than twenty five studies are very closely related to the present study are given as a supportive evidence in the fourth chapter under the heading of discussion on findings. This also has its relevancy with the performance of track and field events in India who are required to train at different intensities and frequency of cycle ergometer training.