REVIEW OF LITERATURE

The history of exercise is older than the history of mankind. Study into exercise probably predates written history. With advent of scientific thinking and methods, research into different training methods started, initially for the purpose of military training, and later for improvement of health and athletic performance. With greater importance on professionalism in sports and increasing amount of fame and money being associated with sports, there has been a plethora of research on training methodologies and its impact on health and performance parameters.

Some of the available literature is listed below:

2.1 AEROBIC PERFORMANCE

Studies involving HIIT have found significant and often dramatic improvement in aerobic capacity even though the total training performed has been relatively less (Burgomaster et al., 2005; Gibala et al., 2006; Little et al., 2010).

Nowak et al. (2015) studied effects of 12 week endurance training program. 34 young women were imparted high-low impact aerobic fitness training. Significant increase in maximum oxygen uptake was observed in underweight women. Overweight and normal weight women did not show the above change, although other changes were noticeable.

Smith-Ryan et al. (2015) studied HIIT in overweight and obese men. They found that over a period of 03 weeks, two different modalities of HIIT resulted in increase of \( \text{VO}_{2\text{max}} \) which was, however, not significant.

Mohr et al. (2014) compared the effects of high intensity swimming training with moderate intensity swimming on cardiovascular health status of mild hypertensive sedentary premenopausal women. It was found that among 62 women, resting heart rate declined by 5 beats per min in both high intensity and moderate intensity continuous exercise group, which was significant. There was also an improvement in Yo–Yo running performance in both, with high intensity group showing greater improvement.
Review of Literature

Stöggl and Sperlich (2014) studied the concept of polarized training and compared it with more traditional concepts of high volume training, threshold training and high intensity interval training in 48 athletes from running, cycling, triathlon, and cross-country skiing. Based on heart rate controlled incremental workload over 9 weeks, work economy and VO$_{2\text{max}}$ were measured. While work economy was found to be similar across the groups, greatest increase in VO$_{2\text{max}}$ was seen in polarized training.

Kilen et al. (2014) investigated high-intensity interval training against traditional training for 12 weeks in 41 elite swimmers. The training volume in case of HIIT group was half of that of traditional training. In spite of greatly reduced volume, there was no observed improvement or deterioration in time performance or oxygen uptake between the groups.

Ouerghi et al. (2014) studied HIIT as opposed to traditional soccer training and no training in 24 young male soccer players over a period of 12 weeks. They found that high intensity interval training produced greater increase in both maximal aerobic velocity and maximal aerobic capacity. This difference in favor of HIIT was evident at 6 weeks and got further accentuated after 12 weeks.

de Araujo et al. (2012) compared endurance training with HIIT on endurance and health related parameters in 30 obese children in the age group 8 – 12 years over a period of 12 weeks. The high intensity interval training sessions lasted around 70% less than endurance training sessions. Both groups showed comparable improvement in absolute relative VO$_{2\text{max}}$ and peak velocity.

Astorino et al. (2012) studied effect of HIIT on cardiovascular function, VO$_{2\text{max}}$, and muscular force over 6 sessions of HIIT in a span of 2-3 weeks in 20 young, healthy adult men and women. The authors found significant improvement in VO$_{2\text{max}}$. No change was noticed in resting blood pressure, heart rate or force production.

Astorino et al. (2012) studied the effect of 6 days of HIIT on rating of perceived exertion (RPE) and leg pain on 11 men and 9 women over 2-3 week period. They realized that RPE and leg pain were significantly decreased after 6 days of HIIT as compared to control.
Fernandez et al. (2012) compared the effects of HIIT and repeat sprint training on aerobic fitness, tennis specific endurance, linear and repeat sprint ability, and jumping ability on 31 competitive male tennis players over 6 weeks. The study showed that high-intensity interval training induced greater improvements in tennis-specific endurance while repeated-sprint training led to a significant improvement in repeated-sprint ability. Both training interventions showed similar improvements in general aerobic fitness.

Ziemann et al. (2011) studied effects of HIIT on aerobic parameters in 21 young, recreationally active males. After an experimental protocol of 6 weeks, they observed that there was a significant increase in aerobic and anaerobic performance in high intensity interval training group as compared to the control group.

Astorino et al. (2011) studied gender specificity of adaptations to 6 days of low volume, high-intensity training. In a study population of 16 young, active men and 13 young, active women, suitably divided in experimental and control groups, both men and women were found to have similar magnitude of change of VO\textsubscript{2max}, VCO\textsubscript{2max}, ratio of peak to mean power output, and reduction in respiratory exchange ratio and pulse rate during sub maximal exercise.

Dunham and Harms (2011) investigated the effects of high intensity interval training on pulmonary function and compared it against endurance training on 15 individuals. They found that while both groups showed significant improvement in VO\textsubscript{2max} and 5 mile time trial, there was no significant difference the two groups over a 4 week protocol.

Metcalfe et al. (2011) studied beneficial effects of reduced-exertion HIIT in terms of insulin sensitivity and aerobic capacity on 13 men and 16 women over a 6 week protocol. They found significantly superior improvement in aerobic capacity and glucose and insulin response to a 75-g glucose load after reduced-exertion HIIT as compared with low-intensity cycling in both men and women.

Gosselin et al. (2011) studied metabolic response of different high intensity aerobic interval exercise protocols in 8 young active subjects and found that a high intensity, low rest interval training regime over 3 weeks resulted in highest benefits in
highest \( VO_{2\text{max}} \), heart rate, rating of perceived exertion, and blood lactate with lowest caloric expenditure.

Støren et al. (2011) investigated the extent by which high aerobic intensity interval training and reduced training volume influences \( VO_{2\text{max}} \) and time trial performance in a case study involving an elite national cyclist and noticed an improvement in \( VO_{2\text{max}} \) and time trial performance but no effect in cycling economy was reported.

Hafstad et al. (2011) studied effects of HIIT on substrate utilization and oxygen consumption in the heart of mice after 10 week of HIIT as compared to moderate intensity training. They realized that while both modalities improved heart weight-to-body weight ratio by around 10%, only HIIT altered cardiac substrate utilization by increasing glucose oxidation and reducing fatty acid oxidation, while simultaneously increasing cardiac maximal mitochondrial respiratory capacity.

Sperlich et al. (2011) compared effects of 5 weeks of HIIT and volume training on \( VO_{2\text{max}} \), 1,000-m time, and sprinting and jumping performance on 19 male soccer players with a mean age of 14 years. It was found that HIIT resulted in significantly higher \( VO_{2\text{max}} \) increase and 1,000-m time decrease as compared to volume training, with similar increase in sprint performance and no effect in jumping performance.

Ziemann et al. (2011) studied the intensity of aerobic and anaerobic benefits of HIIT performed at a work-to-rest ratio of 1:2 on 21 recreationally active male volunteers over a 6 weeks protocol and reported improvement in \( VO_{2\text{max}} \), anaerobic threshold, work output, glycolytic work, mean power, peak power and max power and significant reduction in 15 min post exercise lactate accumulation.

Sperlich et al. (2010) studied training in 26, 9-11-year-old swimmers over 5 week protocol of HIIT versus high volume training on competition performance, \( VO_{2\text{max}} \) and rate of maximal lactate accumulation. Maximal lactate accumulation increased following HIIT and decreased after high-volume training, while \( VO_{2\text{max}} \) increased following both interventions. However, the increases in competition performance, maximal lactate accumulation and \( VO_{2\text{max}} \) following HIIT were achieved in significantly less training time.
Whyte et al. (2010) studied the effect of 2 weeks of very high intensity sprint interval training on metabolic and vascular risk factors in 10 sedentary overweight/obese men. There was improvement in maximal oxygen uptake, mean wingate power, insulin sensitivity index. Both resting fat oxidation rate and resting carbohydrate oxidation in the fasting state were significantly lower 24 hours post-intervention, but did not persist 72 hours post-intervention. In addition, significant decreases in and hip circumferences were observed.

Driller et al. (2009) studied effects of HIIT in well-trained rowers as compared with continuous training. 10 rowers were trained for 4 weeks, following which HIIT showed greater improvements in 2000-m time, 2000-m and relative VO$_{2\text{max}}$.

Nemoto et al. (2007) examined effects of high-intensity interval walking training and moderate-intensity continuous walking training on thigh muscle strength, peak aerobic capacity and blood pressure on 60 men and 186 women (mean age 63 years) over 5 months and found all parameters to be significantly higher in high intensity interval walking training group.

Helgerud et al. (2007) compared the effects of aerobic endurance training at different intensities and with different methods matched for total work and frequency and measured maximal oxygen uptake (VO$_{2\text{max}}$), stroke volume of the heart, blood volume, lactate threshold and running economy of 40 healthy, nonsmoking, moderately trained male subjects over 8 week period by 4 different protocols. Of all the groups, high-intensity aerobic interval training resulted in significantly increased VO$_{2\text{max}}$ compared with long slow distance and lactate-threshold training intensities.

Most of the data available shows the equivalence or superiority of high intensity interval training when compared with slow continuous training when it comes to aerobic performance. The equivalence, whenever reported, is achieved using lower exercise time or caloric expenditure. Results are similar across both sexes and almost all age groups studied. However, barring a few studies, the sample size in most of the studies is very small. Many studies have in fact experimental population of less than 10. Extrapolating this data on the general population becomes difficult.
Most of the studies have used the opportunity to study other parameters as well. Anthropometric profile, lipid profile, peak lactate levels and glucose tolerance are some of the most commonly studied parameters. Some studies which are focusing on the other parameters alone are limited below.

### 2.2 Anthropometric Profile

Many studies have focused on the ability of body to change body composition. Most studies have noted the ability of exercise to reduce weight and body fat, either as a sum of skin–fold thicknesses or expressed as body fat percentage (Nowak et al., 2015; Nybo et al., 2010). These studies have also focused on the ability of exercises to increase muscul arity or lean mass. The duration of interventions across studies has been highly variable, as have been reference population and sample size.

Nowak et al. (2015) studied effects of 12 week endurance training program. 34 young women were imparted high-low impact aerobic fitness training. Significant decrease in weight, Body Mass Index (BMI), Fat Free Mass (FFM), total body water, fat percentage and all analysed skin folds were observed only in overweight and not normal weight group. In underweight women, increase in weight and BMI were observed without significant change in body fat.

Nybo et al. (2010) compared effectiveness of brief intense interval training with prolonged exercise and strength training for promoting health in 36 untrained men and reported superior improvement in cardiorespiratory fitness after 12 week intense interval training, with similar glucose response. The intense interval training showed inferior lowering of resting HR, fat percentage, and reducing the ratio between total and HDL plasma cholesterol compared to prolonged exercise group. Total bone mass and lean body mass increased only in strength training group.

These studies have not demonstrated any dramatic and marked difference between the outcomes in favour of HIIT. In fact, there seems to be tendency to favour SCT in case of Nybo et al. (2010).

### 2.3 Peak Lactate

Studies into lactate have revolved around peak lactate accumulation and lactate curve. Many of these have combined measurements with that of aerobic power, anaerobic power and strength parameters.
Dalleck et al. (2010) studied the possibility of interval training at supra maximal intensity one and two days/wk in addition to habitual training achieving improvements in lactate threshold in a dose response manner over a 6 week period in 20 physically active individuals. They found that Lactate Threshold (LT) responded differently to 1 day/wk and 2 days/wk of interval training. They opined in favor of dose - response relationship between frequency of interval training and the quantum of improvement in lactate threshold.

Tanisho and Hirakawa (2009) compared intermittent and continuous training for endurance capacity on 18 lacrosse players over 15 weeks of training. Maximal anaerobic power, mean power output and fatiguiability increased significantly after interval training. The change was more noticeable in final stages of a 10 set exercise.

2.4 LIPID PROFILE

While role of exercise has generally been recognized in improving lipid profile, debate in the best modality still continues.

Stasiulis et al. (2010) studied changes in body composition, blood lipid and lipoprotein levels in young women between 18 – 24 years of age (n=19) during the period of two-month aerobic cycling training. Body weight and body mass index started to decrease after 2 weeks and became significantly lower after 6 and 8 weeks. Decrease in body fat mass was found to be significant after 2 and 8 weeks of aerobic training. A significant increase in HDL was observed after 4, 6, and 8 weeks, while significant decrease in triglyceride level was observed after 2-week training.

Musa et al. (2009) studied the impact of an 8-week program of high-intensity interval training on lipid profile of 36 untrained men ages 21-36 years over 8 weeks of training. They found significant pre- to post training changes in HDL and TC/HDL, but no significant changes in TC.

2.5 GLUCOSE TOLERANCE

Studies on glucose tolerance have been conducted on euglycemic as well as hyperglycemic populations.
Little et al. (2011) studied the effects of 2 weeks of low-volume high-intensity interval training on glucose control using 24-h continuous glucose monitoring under standardized dietary conditions and muscle mitochondrial capacity in biopsy samples (vastus lateralis) on 8 type 2 diabetes patients. They found reduction in 24 hour blood glucose concentration and 3 hr post prandial area under glucose curve as well as increased muscle mitochondrial capacity both in terms of mitochondrial enzymes action and mitochondrial protein content.

Ciolac et al. (2010) studied 45 healthy young normotensive women at high familial risk for hypertension for comparison of the effects of high-intensity aerobic interval training and moderate exercise on hemodynamic, metabolic and neuro-humoral abnormalities and opined that both are equally effective in improving blood pressure, insulin response and insulin sensitivity, but interval training was superior for improving cardiorespiratory fitness.

Babraj et al. (2009) administered 2 weeks of supervised extremely low volume high-intensity interval training with 250 kcal of work each week on 16 young men over 2 weeks and reported significant reduction in area under the plasma glucose, insulin concentration-time curves and improved insulin sensitivity.