SUMMARY

7.1 INTRODUCTION

Exercise training is typically considered routine physical activity that increases functional exercise capacity for which the gold standard is maximal exercise capacity (VO$_{2\text{max}}$). Exercise training usually also effects body composition, especially lean body mass (Schauer et al., 2009, Bandenhop et al., 2009)

Competition performance is considered the benchmark of any form of training (Cregg, 2013). On the other hand, regular endurance training also results in improvement in physical standard (Sloan et al., 2011). For this purpose, ACSM recommends physical activity of moderate intensity for a minimum of half an hour daily, 5 days a week, or high intensity aerobic exercise on 3 days a week lasting at least 20 min for the entire healthy adult population (Haskell et al., 2007).

The traditional model of training encompasses continuous sustained activity for a longer distance and duration, is sub – maximal in intensity (Katch, McArdle and Katch, 2011), and has been used since long time as the way towards improvement of aerobic power (Cregg, 2013). One of the forms of such slow continuous training requires training continuously for 20 – 30 min at around 70 % of maximal effort (Katch, McArdle and Katch, 2011). Due to its sub – maximal nature, the entire exercise is performed in a state of relative comfort.

Notwithstanding the relative comfort, a majority of population is unable to follow this regime, mainly due to constraints of time (Booth et al., 1997). A need therefore arises of a more time efficient method of training which an provide superior results in a shorter time frame of activity, focusing both on enhancing aerobic fitness as well as improving physical performance (Hottenrott et al., 2012)

A possible solution to the above has been the practice of interval training, wherein the individual trains at a very high intensity for brief duration followed by periods of rest, with multiple repetition of the same prescribed exercise – recovery interval (Katch, McArdle and Katch, 2011, Hottenrott et al., 2012). A popular High Intensity Interval Training method used by athletic trainers and professional coaches
was described by Cregg (2013) as consisting of 10-300 s of very high intensity interspersed with rest – either active or passive. It consumes lesser time, permits individuals to perform higher volume of high intensity efforts, and has beneficial effect on aerobic capacity (Cregg, 2013). The physiological challenges of HIIT are similar to those of Slow, Continuous Training (Gosselin et al., 2011). In HIIT, much more time is spent in active or passive recovery than in actual exercise (Cregg, 2013).

HIIT has already been established as an effective method for improvement in VO$_{2\max}$ (Whyte et al., 2010, Burgomaster et al., 2008; Helgerud et al., 2007; Perry et al., 2008; Tremblay et al., 1994; Warburton et al., 2005). Hottenrott et al. (2012) further established a dose – response relationship in HIIT in terms of peak intensity and frequency of load, and VO$_{2\max}$ as response.

Many other effects of aerobic training have been documented, chief of which include delayed onset of OBLA, decreased rate of lactate formation, increased lactate clearance, increased lactate tolerance, preferential utilization of fat as fuel, reduction in body fat, faster recovery of heart rate, lower body fat levels, and psychological benefits (Katch, McArdle and Katch, 2011), improved insulin response and glucose tolerance, improvement in HDL levels, drop in total cholesterol and triglycerides (Regensteiner et al., 2009).

Considering the great difference in time required between the traditional model of slow, continuous training and High Intensity Interval Training and its subsequent implication on performance seeking athletes and health seeking working population, it is natural to question the relative efficacy of the two models (Hottenrott et al., 2012). The question raised and debated by Åstrand and Rodahl (1986) in Textbook of Work Physiology about relative superiority of the two methods (Seiler and Tønnessen, 2009), has also been reflected in the recent exercise physiology books. Katch, McArdle and Katch (2011) considered that superiority of one method over the other has not been proved.

Comparison of HIIT and SCT has been carried out using different protocols and durations on the above parameters. Mohr et al. (2014) found HIIT to cause greater decrease in Resting Heart Rate in swimmers. Kilen et al. (2014) found similar values in
swimmers for oxygen uptake and time performance in spite of decreased training volume. Ouerghi et al. (2014) found superior gains for HIIT in soccer players while de Araujo et al. (2012) noticed comparable effects among obese children for Peak velocity and oxygen uptake. Many other studies (Gosselin et al., 2011; Støren et al., 2011; Ziemann et al., 2011) showed similar results. The relative comparability of the two methods on effects of body fat, lipid profile and glucose tolerance was also noticed in many studies (Nowak et al., 2015; Nybo et al., 2010; Stasiulis et al., 2010; Musa et al., 2009; Little et al., 2011; Ciolac et al., 2010; Babraj et al., 2009).

The studies were generally conducted on a specific subset of population consisting of elite or sub-elite players of a particular game, or of a specific group like obese or pre-diabetic. Further to this, the sample size was essentially small, and ranged from 8 (Gosselin et al., 2011) to 62 (Mohr et al., 2014). The study by Nemoto et al. (2007) on 60 men and 186 women is an exception which, however, had a mean age of participants as 63 years, and showed significantly higher in high intensity interval walking training group over 5 months of training.

There was a complete lack of studies on Indian population in literature. With this in mind a pilot study was conducted school going, non-athletic male Indian population (Upadhyay et al., 2010) which showed significantly greater improvement in VO$_{2\text{max}}$ after 6 weeks of HIIT when compared to SCT over 6 weeks of training. Based on the results of the pilot study, the present study was conceptualized for the young adult male population.

7.2 OBJECTIVE

This study aims to study the effect of 06 weeks of high intensity interval training of healthy adult population consisting of healthy individuals and recreational athletes and compare it with the effect after 06 weeks of slow continuous training for the following parameters

1. aerobic performance
2. anthropometric profile
3. peak lactate level
4. lipid profile and
5. glucose tolerance

7.3 METHODOLOGY

Research Design - Different subject experimental design

7.3.1 Subjects: The study was carried out at Guru Nanak Dev University, Amritsar, and nodal centers of Sports Medicine Centre, Roorkee.

238 young adult male volunteers were randomly assigned to either a high-intensity interval training (HIIT) group or a slow continuous training (SCT) group using block randomisation.

7.3.2 Inclusion Criteria

– Male
– Age > 18 yrs, < 30 yrs
– BMI > 16, < 25 kg/m\(^2\)
– Recreationally active, with no history of competitive sports participation
– Absence of any health related complication in past 01 yrs
– Absence of any disease as elicited by history and routine medical examination

7.3.3 Exclusion Criteria

– Physical Deformity
– Diagnosed or suspected lifestyle disease
– known musculoskeletal or cardiorespiratory disease
– Competitive sports participation at State level or above / professional training for the same

All subjects were instructed to continue normal daily activities and to refrain from beginning any other training until the completion of the study.
7.3.4 Experimental Protocol: All subjects were administered the following tests prior to beginning of exercise intervention.

1. Body composition analysis using 4 electrode Bioelectric impedance analysis (BODYSTAT 1500MDD).
2. Oral GTT: Venous blood sample for overnight fasting and post prandial blood glucose analysis after 02 hrs of administration of 75 g of glucose using semi-auto analyser (MISPA PLUS) using GOD – POD method end point (Trinder,s method).
3. Lipid Profile: Venous blood sample after 14 hr fasting was subjected to Lipid Profile analysis for Triglycerides, Total Cholesterol, HDL and Total/HDL Ratio,
4. Heart Rate: Resting Heart Rate, Peak Heart Rate and Heart rate during active recovery at 02, 03 and 05 min post exercise were recorded using Heart Rate monitor (Polar S 410 Heart Rate monitor)
5. Resting and Peak lactate analysis: Capillary sample was collected from pulp of finger and analysed immediately using YSI 1500 Sport Lactate Analyser. Sample was collected before the exercise (Resting sample) and 02 min after termination of exercise (peak lactate sample).
6. Endurance: Endurance was tested by using 20 m Shuttle test (Beep test)

7.3.5 Experimental procedures: The subjects were randomly divided into High Intensity Interval Training (HIIT) group and Slow Continuous Training (SCT) group by block randomization. Each group was assigned under a supervisor to ensure that training was carried out as per the required protocol. Training given to each group will be as under.

High Intensity Interval Training (HIIT) group underwent the following training

1. Frequency : 03 sessions per week X 06 weeks
2. Intensity : maximal
   Training at velocity equal to maximum velocity achieved in Bleep test
3. Type : Interval
   Training/Active rest – 30s/30s
   05 reps per set
   04 sets per session with 03 min rest between sets

4. Duration : Exercise time – 10 min/session
   30 min/week
   Total time – 26 min/session

**Slow Continuous Training (SCT) group** underwent the following training

1. Frequency : 05 sessions per week X 06 weeks
2. Intensity : sub – maximal
   Training at velocity equal to 60 – 70% of maximum velocity achieved in Bleep test
3. Type : Continuous
4. Duration : Exercise time – 30 min/session
   – 150 min/wk

**Cool down:** All subjects underwent a supervised warm up, cool down and stretching

7.3.6 **Experimental testing:** All the tests conducted as part of pre – experimental testing were repeated after 03 weeks and 06 weeks of testing.

7.4 **RESULT AND ANALYSIS**

Given below is the summary of result in tabulated form.
### Table 7: Summary and comparison of pre and post test results in HIIT and SCT groups

<table>
<thead>
<tr>
<th>Parameter</th>
<th>HIIT (n=119)</th>
<th>Change (significance)</th>
<th>SCT (n=119)</th>
<th>Change (significance)</th>
<th>Difference in (significance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>20.25±2.25</td>
<td></td>
<td>20.32±2.99</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.71±0.067</td>
<td></td>
<td>1.71±0.045</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>67.02±6.97</td>
<td>64.91±6.65</td>
<td>66.01±5.15</td>
<td>62.48±4.80</td>
<td>3.52±0.86 **</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>23.05±2.99</td>
<td>22.32±2.84</td>
<td>22.60±2.27</td>
<td>21.39±2.12</td>
<td>1.21±0.31 **</td>
</tr>
<tr>
<td>Body Fat (kg)</td>
<td>15.62±5.24</td>
<td>12.30±4.43</td>
<td>15.31±4.32</td>
<td>11.34±3.58</td>
<td>3.97±1.06 **</td>
</tr>
<tr>
<td>Lean Mass (kg)</td>
<td>51.39±4.28</td>
<td>52.61±4.43</td>
<td>50.70±2.90</td>
<td>51.14±2.92</td>
<td>0.44±0.73 **</td>
</tr>
<tr>
<td>BMR (kcal)</td>
<td>1619±135</td>
<td>1657±140</td>
<td>1597±91</td>
<td>1610±92</td>
<td>14±22.90 **</td>
</tr>
<tr>
<td>Peak Lactate (mMol/L)</td>
<td>7.93±0.70</td>
<td>10.29±1.03</td>
<td>8.08±0.70</td>
<td>9.90±1.02</td>
<td>1.82±1.06 **</td>
</tr>
<tr>
<td>VO²max (mL/kg/min)</td>
<td>34.29±3.50</td>
<td>41.40±3.67</td>
<td>33.97±3.72</td>
<td>40.16±3.16</td>
<td>6.19±2.75 ***</td>
</tr>
<tr>
<td>Vmax (km/hr)</td>
<td>11.42±0.47</td>
<td>12.43±0.55</td>
<td>11.32±0.67</td>
<td>12.24±0.49</td>
<td>0.92±0.62 **</td>
</tr>
<tr>
<td>TotalCholesterol (mg/dL)</td>
<td>162.71±25.53</td>
<td>153.76±21.1</td>
<td>168.56±21.32</td>
<td>158.03±21.19</td>
<td>10.53±8.72 **</td>
</tr>
<tr>
<td>TriGlicerides (mg/dL)</td>
<td>126.74±30.36</td>
<td>117.45±28.60</td>
<td>125.71±33.69</td>
<td>117.00±30.21</td>
<td>8.71±11.54 **</td>
</tr>
<tr>
<td>HDL (mg/dL)</td>
<td>48.61±9.71</td>
<td>55.37±8.14</td>
<td>46.44±6.59</td>
<td>55.39±7.10</td>
<td>8.96±4.94 **</td>
</tr>
<tr>
<td>TC/HDL</td>
<td>3.43±0.65</td>
<td>2.82±0.47</td>
<td>3.68±0.59</td>
<td>2.89±0.47</td>
<td>0.80±0.36 **</td>
</tr>
<tr>
<td>Fasting Glucose (mg/dL)</td>
<td>83.40±7.09</td>
<td>82.77±6.51</td>
<td>82.12±7.51</td>
<td>81.53±6.33</td>
<td>0.59±3.96 **</td>
</tr>
<tr>
<td>Post Prandial Glucose (mg/dL)</td>
<td>97.75±7.77</td>
<td>101.32±8.61</td>
<td>95.25±7.97</td>
<td>100.95±7.29</td>
<td>5.70±8.28</td>
</tr>
</tbody>
</table>

Note: Bold figures represent significant difference

**p value < 0.005, *p value < 0.05, ***p value < 0.001**
The pre experimental values were statistically comparable. Statistical analysis shows that HIIT was effective in improving weight by 3.14% (p<0.005), BMI by 6.16% (p<0.005), body fat by 21.24% (p<0.005), lean mass by 2.36% (p<0.005), BMR by 2.36% (p<0.005), peak lactate by 29.81% (p<0.005), VO_{2max} by 20.75% (p<0.001), Vmax by 8.83% (p<0.005), total cholesterol by 5.50% (p<0.005), triglycerides by 7.33% (p<0.005), HDL by 13.90% (p<0.005), TC/HDL by 17.70% (p<0.005) and fasting glucose by 0.76% (p<0.005).

SCT was effective in improving weight by 5.35% (p<0.005), BMI by 5.36% (p<0.005), body fat by 25.95% (p<0.005), lean mass by 0.86% (p<0.005), BMR by 0.86% (p<0.005), peak lactate by 22.51% (p<0.005), VO_{2max} by 18.22% (p<0.001), Vmax by 8.13% (p<0.005), total cholesterol by 6.25% (p<0.005), triglycerides by 6.93% (p<0.005), HDL by 19.29% (p<0.005), TC/HDL by 21.64% (p<0.005) and fasting glucose by 0.72% (p<0.005).

HIIT was more effective than SCT for improvement in lean mass (p<0.005), BMR (p<0.005), VO_{2max} (p<0.005) and fasting glucose (p<0.05)

SCT was more effective than HIIT for improvement in BMI (p<0.005), body fat (p<0.005) and HDL (p<0.05)

Both HIIT and SCT have comparable effect in improvement in weight, peak lactate, maximum velocity, total cholesterol, triglycerides and TC/HDL ratio.

7.5 DISCUSSION

238 adult healthy male volunteers participated in the study. The results show that in spite of spending much less time on training, HIIT shows greater improvement in VO_{2max} than SCT, and has similar response to SCT in lactate, lipid and glucose profile. While improvement in lean mass was greater in HIIT, parameters like body fat, weight and BMI show better result with SCT, albeit with 5 times of the weekly duration of exercise.

The results appear to be along similar line to that apparent with most of the reviewed literature. While Smith-Ryan et al. (2015) and Astorino et al. (2012) had not noticed any significant difference between the effects of HIIT and SCT with 3 weeks of
training, and Dunham & Harms (2011) over 4 weeks of training, Novak et al. (2015), Kilen et al. (2014) and Ouerghi et al. (2014) had found HIIT type training to be significantly better than SCT type training over 12 weeks of training for improvement in endurance performance.

The effect of peak lactate on exercise has been by some authors. Gosselin et al. (2011) had noticed similar superiority of HIIT for improvement in peak lactate over SCT and other training forms, as had Sperlich et al. (2010). Tanisho and Hirakawa (2009) had noticed significant increase in time to fatigue after HIIT. This result is in same line as the present study.

Dalleck et al. (2010) opined in favour of a dose – response relationship wherein the amount of improvement in lactate profile was dependent on the frequency with which HIIT was performed during training.

When taken together with improvement in \( \text{VO}_{2\text{max}} \), it is quite clear that HIIT provides for better improvement in athletic performance than SCT. This postulate is supported by the studies like those by Driller et al. (2010) in rowers, and Sperlich et al. (2011) in soccer players. Another study on active individuals by Astorino et al. (2012) found decrease in RPE and leg pain after HIIT for same levels of exertion.

It is known that modest increment in fitness by performing physical activity results in significant health benefits. (Hambrecht et al., 2000). The traditional method of Physical activity involves prolonged duration physical activity at a steady state (Katch, McArdle and Katch, 2011). It has the advantage of being physiologically similar to a competition setup (Cregg, 2013; Katch, McArdle and Katch, 2011). However, it leads to accumulation of metabolites like lactate, which limit the maximal intensity that can be performed. The exercise intensity is generally limited to 60 – 70% of maximal effort. Some athletes can take it up to 85% of HRmax, with greater benefits in performance (Katch, McArdle and Katch, 2011).

In general life, as well as in most sports endeavours, it is common to come across small periods of highly intense activity, interspersed with periods of lower intensity effort, relative rest or complete inactivity. Using the same approach for training will facilitate training at much higher intensities by causing much less
accumulation of lactate and lower levels of fatigue (Katch, McArdle and Katch, 2011). In research, this interpretation has been supported by relationship between increased VO2max and improved repeat sprint ability in team sports (McMahon et al., 1998). At the cellular level, Little et al. (2010) had shown that HIIT induced mitochondrial biogenesis in skeletal muscles in humans. They considered SIRT1, nuclear PGC-1alpha, and Tfam as possible mediators in this skeletal muscle mitochondrial biogenesis which resulted in higher muscular mitochondrial concentration and higher aerobic performance.

In relation to anthropometric profile, both the interventions caused decrease in weight in the subjects studied. The overall weight reducing efficiency of SCT was better than that of HIIT over 6 weeks of training. It is therefore imperative to look at components of weight for further explanation. The body fat decrease in case of SCT is superior to that of HIIT. On the other hand, both types of training cause an increase in the lean mass, with HIIT resulting in greater increase in lean mass than SCT.

Exercise causes alteration in body composition by causing preferential fat loss while enhancing exercise capacity, and there is a close correlation between improvement in exercise capacity and amount of fat loss. (Katch, McArdle and Katch, 2011). The present study upholds this concept both in improving performance and decreasing body fat while improving lean mass.

Similarly, both HIIT and SCT of exercise appear to be effective for improving the lipid profile. With the exception HDL, there is no significant difference between the effects of HIIT and SCT. Even in case of HDL, the study marginally favours SCT.

The study had excluded any subject with known Diabetes Mellitus. Hence all subjects were euglycemics. Both forms show a marginal change in fasting and post prandial glucose levels. The quantum of these changes in both instances is less than 1%. However, it cannot be denied that HIIT has significantly higher ability to decrease fasting glucose levels in blood.

Metcalfe et al. (2011) had noticed better glucose and insulin response following HIIT, which was apparent 3 days after the cessation of exercise. Little et al. (2011) had also noticed similar improvement in 24 hr blood glucose concentration and 3 hr post
prandial area under glucose curve following HIIT. Ciolac et al. (2010) noticed equal
effect of HIIT and SCT in young normotensive women on insulin response and insulin
sensitivity. Babraj et al. (2009) had also observed similar glucose lowering effect of
HIIT on area under glucose curve after HIIT in young men.

Even though the level of decrease in fasting glucose levels in not much, the very
fact that the decrease has been observed is very important. More importantly, HIIT is
seen as better in lowering of glucose levels than SCT in healthy young adults. The study
on type 2 diabetics yields similar results.

But the take home message in respect of glucose levels should be the fact that
both forms of exercise are effective in lowering fasting blood glucose, and that HIIT
provides better response using much less exercise time.

7.6 CONCLUSION

The study shows that both HIIT and SCT provide significant health and
performance benefits in healthy adult males over 6 weeks of training while SCT
provides superior gain in aerobic performance while SCT provides superior
improvement in anthropometric profile, and both have similar result in improvement of
peak lactate and lipid profile and glucose tolerance. The benefits achieved during HIIT
require 30 min per week, which is one – fifth of exercise time needed for SCT at 150
min per week.

7.7 CLINICAL RECOMMENDATION

1. HIIT provides superior gains to SCT for improvement in aerobic performance
   and should be included in every program to improve cardio – vascular fitness
   and aerobic performance.

2. HIIT is an effective form of exercise for improvement in Anthropometric, lipid
   and glucose profile, with benefits occurring in one – fifth of the time required
   for SCT, and may be used in place of SCT if time constraint is a limiting factor.