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RESEARCH ARTICLE

EFFECT OF HIGH VOLUME HIGH INTENSITY INTERVAL TRAINING ON PHYSIOLOGICAL PARAMETERS, BODY COMPOSITION AND LOWER LIMB STRENGTH IN LONG DISTANCE RUNNERS : A PILOT STUDY

Sharma Oshin¹, Kadyan Gaurav², Bansal Vishal³ and Dhingra Meenu⁴

1. (MPT SPORTS) Department of Physiotherapy, Indian Spinal Injuries Centre-Institute of Rehabilitation Sciences.
2. MPT(Th(Sports Medicine)-Assistant Professor, Indian Spinal Centre-Institute of Rehabilitation Sciences.
3. (MD,DNB,PhD,MNAMS) Assistant Professor, Vallabhai Patel Chest Institute, University of Delhi, New-Delhi-110007.
4. (Ph D)-Senior Scientific Officer, Sports Authority of India, Jawaharlal Nehru Stadium, New Delhi-110003.

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Abstract

Background: Long distance running is a form of continuous running over distance of at least three kilometers. Physiologically it is aerobic in nature and requires stamina as well as strength. Regular aerobic endurance training improves physical fitness and recovery rate. High-intensity interval training (HIIT) is a type of exercise training characterized by brief, intermittent bursts of vigorous activity, interspersed with periods of low intensity activity. High intensity interval training appears to be an efficient and practical way to develop potentially large effects on exercise capacity and small time requirement.

Objectives: To evaluate the effect of high volume HIIT on Cardiac autonomic function, aerobic capacity, knee strength, body composition analysis and response to graded normobaric hypoxia in long distance runners.

Methodology: A sample of 10 novice long distance runners within the age 21-30yrs males were recruited and informed about the study. Subjects were divided into two groups - Group -1 (control group) which did only long distance running training and Group-2 (experimental group) did long distance running training along with high volume high intensity interval training. Subjects in Group-2 received 1 set of HIIT thrice a week for 6 weeks. Measurements of all criterion measures were collected before and after the training period of 6 weeks. Pre- training measurements were taken a day before the start of training and post -training measurements were done a day after completion of training.

Results and Conclusion: There were non-significant changes in cardiac autonomic function, aerobic capacity, knee strength, body composition analysis and response to graded normobaric hypoxia

Corresponding Author:- Oshin Sharma, Dr. Vishal Bansal

Address:- Department of Physiotherapy, Indian Spinal Injuries Centre-Institute of Rehabilitation, Sciences and Vallabhai Patel Chest Institute, University of Delhi.

after High volume high intensity interval training was observed. However, there was a trend towards improvement in these parameters.

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Introduction:-

Long distance running is a form of continuous running over distance of at least three kilometers. Regular aerobic endurance training improves physical fitness and recovery rate.¹ High intensity interval training (HIIT) is generally characterized by repeated sessions of brief, intermittent exercise, typically at intensities that elicit > 85% of peak oxygen uptake (VO_2 peak), and interspersed by periods of rest or low intensity exercise for recovery.² Cardiac autonomic function is measured through Heart rate variability (HRV) which is considered a non-invasive, reliable method to assess changes in autonomic nervous system (ANS) occurring with training, assessing fatigue states, constitutes complementary tools that allows to achieve a greater relevance and accuracy of the athletes fitness and results.⁴ High frequency R-R interval power is associated with cardiac parasympathetic activity whereas the low frequency components are associated with both parasympathetic and sympathetic activity. The ratio of low to high frequency power is considered as the "sympatho-vagal balance". Both high and low frequency parameters were found to decrease at altitude although the ratio of low to high frequency power increased.⁵ The increase in the ratio is believed to imply that the sympathetic activity is dominant as compared to parasympathetic. These findings imply that acute exposure to hypoxia causes decreased parasympathetic and increased sympathetic tone and during acclimatization there is a progressive shift toward still higher sympathetic tone.⁶ It has been demonstrated that the effects of different volumes of HIIT on maximal oxygen consumption (VO_{2max}) and concluded that both high and low volume of training significantly improved VO_{2max} .⁶ According to Ed Coyle model proposed that endurance performance is chiefly a function of VO_{2max} , efficiency during submaximal exercise (which is more commonly termed economy during running), and the fractional utilization of the VO_{2max} . The former is important because it determines the performance VO_{2max} clearly cannot exceed the VO_{2max} : efficiency is important because it determines the performance speed corresponding to a given VO_{2max} , that can be sustained for a given distance or exercise duration. While longer term HIIT may invoke central cardiovascular adaptations which underpin an increased VO_{2max} , it appears, at least in the short term, that HIIT mainly stimulates peripheral muscle metabolic adaptations. Also, in terms of Coyle's model, HIIT-induced improvements in substrate utilization and oxidative energy turnover may therefore enhance endurance capacity by increasing the fractional utilization of the VO_{2max} .³ Although typically an integral component of training programs for the enhancement of athletic performance, effect of High volume HIIT on the performance at high altitude in endurance-trained individuals is sparse.

Materials and Methods:-

A pre and post-test experimental design was used in our study. A sample of 10 long distance runners subjects who meet the inclusion criteria and willing to participate in the study voluntarily were recruited in the study. Out of a total of 10 Subjects, 2 subjects were dropped out from study.

Inclusion Criteria:

1. Long distance runners aged 21-30yrs males.
2. Subjects within normal body mass index :18- 24 kg/m²

Exclusion Criteria:

1. Any known medical history including history of unstable angina, recent cardiac infarction, uncompensated heart failure, severe valvular illness, pulmonary disease, uncontrolled hypertension, kidney failure, autonomic dysfunction, diabetes.
2. Any musculoskeletal disorders, psychic disorder and drug users specially drug affecting nervous system.
3. Any history of alcohol consumption or smoking, tobacco intake, heavy caffeine addict.

Participants were then randomly divided into two groups by computer generated randomization

Group 1: (Control group): comprised of participants that were given long distance running training.

Group 2: (HIIT group): comprised of participants that were given HIIT in addition to long distance running training. Group 2 performed HIIT as running on a treadmill.

Outcome measures were:

1. Cardiac autonomic function
2. Aerobic capacity
3. Knee strength
4. Body composition analysis
5. Response to graded normobaric hypoxia

Procedure:-

The study was approved by the Institutional Research review committee and the Institutional Ethical Committee of Indian Spinal Injuries Centre and Vallabhai Patel Chest Institute. A sample of 10 novice long distance runners was taken. All subjects were given a detailed explanation of the procedure and a written consent was obtained. Demographic data of subjects was collected and assessment was performed. The subjects were randomly allocated into the following two groups by computer generated random number and tables.

Group 1: (Control group): comprised of participants that were given long distance running training.

Group 2: (HIIT group): comprised of participants that were given HIIT in addition to long distance running training.

Intervention was given 41 minutes, 3 days a week for 6 weeks.

Procedure for High Volume High Intensity Interval Training:

1. Subjects were familiarized with the training for 3-4 days prior to actual training.
2. Before starting exercise protocol age predicted maximum heart rate (MHR) was calculated by prediction equation⁴ - $[206 - (0.88 \times \text{age})]$ from which the required intensity percentage of MHR) of training was identified and then corresponding speed to that intensity was achieved.
3. Exercise group performed HIIT as running on a treadmill.
4. Initially, a warm up was performed at an intensity of 60%MHR for 10 minutes.
5. The group performed high volume HIIT- 4 bouts of running at 85-95%MHR for 4 minutes interspersed with 3 minutes of active recovery at 70%MHR per session thrice a week for 6 weeks.
6. At the end of each training session, there was a cool down period of 5 minutes at an intensity of 50%MHR.
7. Standardized verbal encouragement was provided throughout the protocol.
8. Total time of training will be 41 minutes.

We took five parameters as outcome measures. They were:**Cardiac Autonomic Function:**

Procedure for Cardiac autonomic function - Cardiac autonomic function is measured through Heart rate variability (HRV). Heart rate variability assessment was carried out as per the recommendations of the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology.⁷ ECG was recorded using standard lead II and fed into a bio-amplifier and digitized using an analog-to-digital converter and then displayed on a computer with the data acquisition and analyzing software. ECG was recorded continuously and time stamped with level of hypoxia. Regions of artifact was eliminated. No recordings with more than 1% ectopic beats or 5% artifact was considered for analysis. After correction the cardiac rhythm data was analyzed. Only normal-to-normal (NN) beat intervals were included in the analysis. Both time domain and frequency domain analysis using non-parametric Fast Fourier Transform (FFT) were performed according to standard guidelines.

VO₂ Max:

Procedure for measuring Aerobic capacity (VO₂ max):-The subjects underwent a maximal graded incremental exercise test on a cycle ergometer (Monark Ergometer 839 E) to determine VO₂max using telemetric breath to breath analyzer VO 2000 (Medgraphics, USA). Subjects were seated on the bicycle ergometer and asked to pedal at 60 rpm frequency. During the test, the work rate was increased by 10 W/minute increments after 3 min of unloaded pedaling for warm up. Test was terminated at volitional fatigue, attainment of target heart rate or if VO₂ that increment < 1 ml.kg⁻¹min⁻¹ for ≥ 30 seconds despite an increment in workload. Recovery heart rate was noted for 3 minutes.⁸

Knee Strength:

Procedure for measuring Knee strength :- Subjects warmed up prior to testing by cycling for 5 minutes on a stationary bicycle. After a 1 minute rest period, subjects were familiarized with the resistance machines (leg curl and leg extension) by performing 8-10 repetitions of a light load (~50% of predicted 1RM). After a 1 minute of rest, subjects performed a load (~80% of estimated 1RM) through the full range of motion. After each successful performance, the weight increased until a failed attempt occurred. One minute rests were given between each attempt and the 1RM was attained within 5 attempts and 5 minutes rest separated each test.⁹

Body Composition Analysis:

Procedure for Body composition Analysis :-Body Fat Percentage (BFP) and Fat Free Mass (FFM) was assessed by bio-impedance method using InBody 230 (Biospace, Korea) Body composition analyzer machine as per standard guidelines.⁸The subjects were nil orally for three hours and were asked to void their bladder prior to measurement. The information of age, gender, weight and height was entered into the software program, then the subject would stand over the machine for approximately 1 minute after moistening their hands and feet with a wet gauge. Measurements were performed using 4 pairs of electrodes with passing current into the analyzer's handles (thumb and palm electrodes) and floor scale (ball of foot and heel electrode).Fat Free Mass Index (FFMI) was calculated by whole body fat free mass (FFM)in kilogram divided by square of height (h) in meters (Carl et al., 2012).

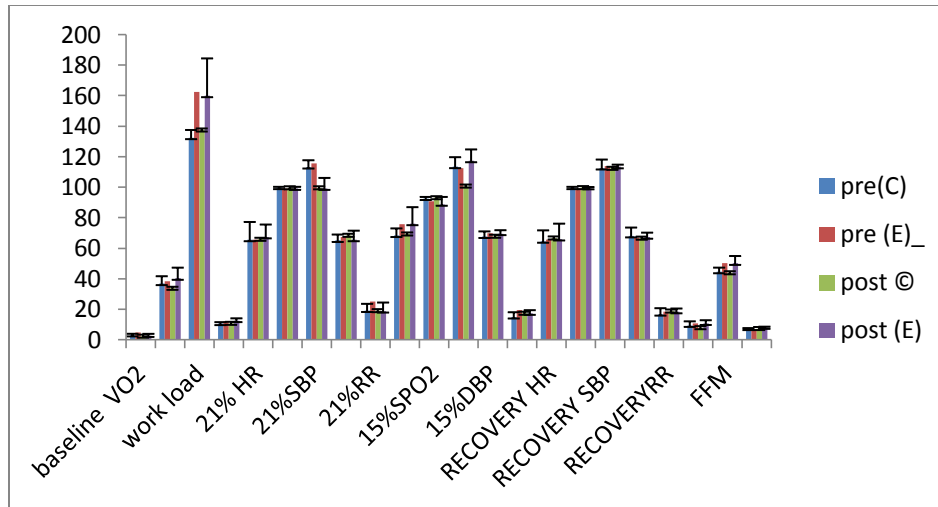
$$FFMI = \frac{\text{Whole body fat free mass (Kg)}}{\text{Height}^2}$$

Hypoxia Exposure:

Procedure for hypoxia exposure :-Subjects were exposed to normobaric, graded hypoxia (FiO₂ ~ 0.19 up till 0.15 in steps of 2% decrement) to assess their physiological responses. They were asked to lie down on a bed in a quiet room maintained at 25°C. Full face mask connected to hypoxia generating machine was placed on them. After stabilization, baseline (i.e. at room air, FiO₂~0.21) recording of blood pressure (BP), heart rate (HR), finger pulse arterial saturation (SpO₂) was done. Continuous ECG was recorded to measure HRV (Heart Rate Variability) and to look for any cardiac depression arising due to hypoxia. Any other symptoms of discomfort such as, breathlessness, sense of uneasiness, chest tightness or heaviness, headache and fatigue etc. was recorded and rated between scale of 0 to 10 (0 means no symptoms and 10 being maximum symptoms). Subsequently, hypoxia generating machine will be switched on and subjects were exposed to FiO₂ of 0.19 for 10 minutes. Continuous recording of SpO₂ and HR was done with finger pulse oximeter to monitor changes in oxygen saturation and HR. ECG was recorded continuously and time stamped with level of hypoxia. BP was recorded at 5 minutes interval. Any appearance or change in symptoms of discomfort was rated and recorded. Level of hypoxia was increased by 2%, i.e. to FiO₂ of 0.17 for another 10 minutes and all the parameters were recorded in the manner explained above. Same process was repeated with subsequent increase in level of hypoxia till FiO₂ reaches 0.15 (altitude level equivalent to 8500 ft or 2500 m). The process was terminated if there were signs of discomfort or derangement in vital parameters.¹⁰

Results:-**Table 1:-** HRV pre –post analysis.

HRV		Control n=4			P VALUE	Experimental n=4		
		PRE	POST			PRE	POST	P VALUE
Time Domain	SDRR(ms)	61.76±18.9	60.97±10.4	0.35	57.13±12.97	62.79±11.97	0.93	
	SDSD(ms)	62.14±26.11	65.27±23.4	0.86	47.008±11.27	63.185±14.42	0.77	
	RMSSD(ms)	62.06±26	65.19±23.4	0.86	46.94±11.25	63.09±14.40	0.77	
	PRRR(%)	40.28±21.4	38.04±19.66	0.91	29.21±13.14	42.7±13.68	0.95	
Frequency Domain	TOTAL POWER (ms ²)	4375.65±2873.4	3732.02±1200.4	0.05	3084.5±1496.8	4594.66±2161.2	0.59	
	LF POWER (ms ²)	1335.97±1086.4	929.7021±243	0.11	1194.25±556.8	1282.824±740.25	0.75	
	HF POWER (ms ²)	1641.67±1111.65	1796.895±910.14	0.70	874.8±499.5	1599.78±897.5	0.52	
	LF/HF (ms ²)	0.80±0.32	0.723889±0.63	0.22	1.68±0.79	0.948±.608	0.40	
Non – Linear Analysis	SD1 (ms)	43.94±18.46	46.15792±16.57	0.86	33.24±7.97	41.96±7.03	0.86	
	SD2 (ms)	74.71±22.38	71.96219±7.93	0.001	73.20±17.4	75.83±18.68	0.82	



Graph1:- Representing pre and post comparison of physiological variables, body composition and knee strength.

The results showed were not statistically significant however a trend towards improvement was seen after the intervention.

Statistical Analysis:

The Statistical package of social science (SPSS) for windows, version 25.0 was used for the Statistical analysis. The normality of the distribution of the data was tested using the Shapiro-wilk test. Analysis was done for 8 subjects who completed the study. Physical characteristics data of the subject includes age, gender, weight, height, BMI, body composition aerobic capacity and knee strength were descriptively summarized. Independent T- test was performed for age, gender, weight, height, BMI, body composition aerobic capacity and knee strength to check the homogeneity of the subjects in both the groups. Paired T- test was used for within group analysis for pre and post intervention regarding both the groups and to test any statistical difference. Statistical significance was set at $p \leq 0.05$

Discussion:-

The results for HRV analysis showed a trend towards increase in time domain(SDRR,SDSD,RMSSD,PNN50), frequency domain(Total Power,LF,HF,LF/HF) and non-linear indices(SD1 ,SD2). Although ,the HRV analysis in our study for long distance runners statistically showed non-significant results. However, there has been significant changes seen in time domain and non-linear analysis (PNN50 and SD2) in control group which shows a shift toward vagal and sympathetic dominance.The statistical difference in the results could be due to small sample size, overtraining in the experimental group as the athletes were practising long distance running training along with High Volume High Intensity Training sessions three times a week which could further lead to overtraining, fatigue and less time for recovery in runners. Also, variation of time and the temperature in HRV analysis could be a major factor in alterations for HRV analysis. Further , in the previous studies it has demonstrated that 7 weeks of HIIT was not sufficient enough to underline a positive effect on the HRV though it induced positive changes on aerobic fitness. These non significant changes in HRV were explained by the accumulation of fatigue after high-intensity exercise. According to the study by Kiviniemi et al., have proved recently that HIIT is superior to traditional endurance training for improving cardiac autonomic function and suggested that improvements in autonomic function post-HIIT are related to an increased vagal or baroreflex-mediated modulation of the SA node may be the cause of the non significant changes. Another study by Koufaki et al. examined the effect of HIIT and continuous moderate intensity exercise training on HRV, aerobic capacity, functional capacity and health-related quality of life in chronic heart failure patients and concluded that none of the training interventions induced changes in cardiac autonomic functioning which is in context with our study. Another study which compared moderate and heavy metabolic interval training showed that enhanced vagal activity and preferable cardiac autonomic modulations are achieved by moderate interval exercise training.⁸

Also, in our study there was a trend towards improvement on VO2 max with High volume high intensity interval training though not stastically . The magnitude of improvement in measures of aerobic exercise performance (VO2max and Paer) is consistent with other short-term training studies in relatively untrained trained young adults(

Bouchard et al., 1999; Helgerud et al., 2007; Matsuo et al., 2014; Nybo et al., 2010; Pollock, 1973; Rognum et al., 2004; Tabata et al., 1996) as compared to our novice long distance runners. In studies with an appropriate steady-state control group, interval training has usually produced a larger increase in VO₂max than nominally similar steady state- Meyer et al. (1990), which represents early post-bypass surgery patients (with a very large margin for improving), other studies have observed ~15% increases in VO₂max per kg BW in HIIT groups over 6-12 weeks of training, compared to ~10% in control groups performing steady state training.¹¹

It was recognized that a high percentage body fat is a strong predictor of CVD risk factors, and a sedentary lifestyle is strongly correlated with obesity. Thus, assessing the percentage body fat after exercise training becomes essential. In the present study, long distance running reduced body fat in control group but was not statistically significant. However, this could be due to alterations in diet plan / nutritional intake of the athlete that was not consistent throughout the study. Thus, this finding resembles other studies comparing volume of continuous moderate intensity training (CMIT) and (HIIT) high intensity interval training. Significant reduction in body fat percentage after LowVolume HIIT may be considered an important finding, as this demonstrates that even LowVolume HIIT is sufficient enough to reduce percentage body fat, and therefore, it may be advocated as a preferred mode for reducing body fat over HighVolume HIIT. Possible underlying mechanisms for HIIT-induced fat loss include increased fat oxidation and decreased appetite. Elevated growth hormone (GH) and catecholamines generated during HIIT are also proposed to contribute to enhanced fat metabolism. In a recent meta-analysis by Wilson et al. found that higher exercise intensities (>80% maximum HRR) resulted in greater effect sizes for body fat lost. However, in a review paper by Boutcher, the author summarized the results of past research by concluding that studies of 6 weeks or less in duration resulted only in negligible fat loss. In addition to the studies cited in Boutcher's article, Astorino et al. also found no changes in body composition over a 2-3 week period. Thus, one of the main limitations of our study was that it was only 6 weeks in length, which possibly explains the negligible effect on fat loss.^{9,12} FFM, which consists of skeletal muscle mass, is an indicator of maximum aerobic capacity, and this study demonstrates no significant improvement in FFM in the (experimental) HIIT group. However, many studies demonstrate no change in FFM after the HIIT program, which is similar to what we observed in our study in HighVolume HIIT group.^{8,12}

HRV under hypoxic condition- In our study the parameters of time domain, frequency domain and non linear HRV indices showed alterations at different percentage of oxygen i.e., FiO₂ 21% - 15% and recovery. Comparison of two groups at 21% FiO₂ and 15% FiO₂ showed the effect of high volume HIIT. Among the selected studies, some had short exposure to hypoxia - of around 6-15 minutes, while others had longer exposure periods of one to twelve hours. Furthermore, the studies used gradual rise protocols or sudden exposure to hypoxia. The length of stay and type of rise to a simulated altitude could generate different cardiac autonomic modulation responses. Likewise, the different levels of oxygen used in the studies, ranging from 19% to 9.6% of FiO₂ also appear to induce different HRV responses. To study the effects of hypoxia is through simulators that reduce FiO₂, without changing the barometric pressure, known as normobaric hypoxia (NH). Similar to our study Haddad et al. focused on the impact of hypoxia on cardiac parasympathetic reactivation measured by HRV after exercise. However, for this review, we considered only the HRV indexes at rest. The section for analysis considered was from the 5th to the 10th min of exposure to 15.4% FiO₂ ~2400m. The HRV indexes presented did not change significantly. Suggesting that the magnitude of hypoxia was not sufficient to cause changes in HRV at rest. However, it was sufficient to cause a delay in cardiac parasympathetic reactivation after a submaximal exercise. In addition, this study sample had good physical capacity, which itself tends to respond to better adjustments in the HRV in stressful situations.¹⁰

Further in previous researches it has been seen that increased muscle protein synthesis after endurance training may be an underlying mechanism for this improved muscle strength after HIIT. Findings of this study revealed increase in muscle strength after HIIT which was statistically non-significant, which contrasts with the previous other literature. Due to ambiguity in the literature, further research is required to examine the effect and duration of HIIT on muscle strength.

Conclusions:-

The present study demonstrated that HVHIIT imparted 3 times per week for 6 weeks can produce favorable improvements but not statistically (increased vagal cardiac control) in HRV, tolerance to high altitude conditions in novice long distance runners. Also, HVHIIT training protocol is equally effective in improving aerobic capacity (VO₂max) and reducing body fat content. Practical implications of these findings would depend on applicability in day-to-day athletic scenarios. However, HVHIIT would be a more effective mode to improve cardiac autonomic

function. As this study was done on novice long distance runners, the results can only be generalized to this population. Future studies are recommended to evaluate effect of HVHIIT on elite athletes, so as to ascertain optimal doses of HVHIIT to improve their cardiac autonomic function and their aerobic capacity.

Limitation of the study:

1. The sample size included in the study was small; there should have been large population of long distance runners for better results.
2. The study can be done on equal number of male and female long distance runners to check the gender difference and performance .
3. Future Recommendations
4. The study can be used as a guide to find the effectiveness of High Volume High Intensity Interval Training in elite athletes /female athletes.
5. HRV analysis may be used to evaluate cardiac adaptations in elite /female athletes.
6. High Volume High Intensity Interval Training can be used as an effective training method for improving aerobic capacity and performance

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