Comparison of Cardiovascular Responses to Exercise and Recovery Pattern in Players

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Abstract

The study was conducted on 149 Punjabi University players preparing for inter university competition during their training camps held at Punjabi University, Patiala. The subjects were administered progressive workloads starting from 50W at 60 rpm on an electrically controlled bicycle ergometer and increased in steps of 25W every minute until the exhaustion of the subject. Blood pressure & minute heart rate were recorded during exercise and recovery at intervals of one minute during the course of exercise and 15 minutes of recovery. On the basis of the study it is concluded that significant differences are demonstrated by different category of players and physical education students in their blood pressure and heart rate responses to varying intensities of exercise and at different points of recovery.

Key Words: Maximal exercise, Recovery, Blood pressure, Heart rate

Introduction

After exercise, bodily processes do not immediately return to resting level. The variation in recovery from light, moderate and strenuous exercise is determined by specific metabolic and physiological processes resulting from each level of effort *(Hultman et al, 1967, Di parampero et el, 1983, Gaesser and Brooks, 1984,)*. During the initial minutes of recovery, even though the muscle is no longer actively working, oxygen demands do not immediately decrease; instead oxygen consumption remains elevated, temporarily. This is due to restoration of metabolic processes to its pre-exercise levels. This consumption, which exceeds the usually required when at rest, has traditionally been referred to as the oxygen debt. A more common term today is excess post exercise oxygen consumption (EPOC) *(Gaesser and Brooks, 1984)*. The EPOC curve has two distinct components: an initial fast component (alactacid debt) and a secondary slow component (lactacid debt) both components of the curve reflect the anaerobic activity that had occurred during exercise. The first phase of recovery is marked by rapidly declining VO_2 and heart rate. It is during this period that tissue stores of the ATP and Phosphocreatine (PCr) depleted in the muscle are restored within 30 seconds and 100% restored within 3 to 5 minutes (*Hultman et al, 1967*).

The ability to maintain muscle performance during high intensity exercise depends on the recovery performance in many individual and team sports. According to *Zafeiridis (2005)* a higher rate of PCr re-synthesis, a greater ability to tolerate buffer and remove H^+ and restore muscle pH and a greater oxidative enzyme activity may accelerate the recovery process.

Many sports such as football, boxing, hockey, wrestling, etc., have intense period of work alternating with short to moderate periods of rest (or reduced

activity), depending upon the specific demands of the sport. Not only is the creatine phosphate, which is the most immediate reserve in the skeletal muscle or for the re-synthesis of ATP, taxed to the maximum during short term high intensity maximum exercise, the fact that muscle and blood lactate concentrations are also significantly elevated after 6 seconds (*Boobis et al, 1983*), and 10 seconds (*Jacob et al, 1983*), following maximum intensity work, exemplifies that glycolysis also present an important source of ATP re-synthesis in short duration exercise. The resulting drop in muscle pH may have a detrimental effect on subsequent performance (*Curtin and Edman, 1989*). The return of exercising muscle towards resting pH and normal CP levels will consequently be an important component of recovery. The high correlation between recovery during intermittent exercise and creatine phosphate re-synthesis are consistent with this theory (*Bogdanis et al, 1996*). A number of studies have concluded that recovery will be facilitated by an enhanced oxygen uptake capacity (*Petersen and Cooke, 1994*). The ability to recover quickly is therefore important in many team sports like football, hockey and in combat sports like boxing and wrestling.

Individual differences exist among sports person to metabolize lactate for example improvement of aerobic fitness plays a great role in recovery. Some studies have supported an association between aerobic fitness and lactate removal (*Tomlin and Wenger, 2001*) following high intensity exercise, whereas some others have failed to confirm an association (*Evans and Cureton, 1983*; *Oothuyse & Carter, 1999*).

The present study has been conducted with an aim to compare the exercise and recovery patterns on common cardiovascular variables like heart rate and blood pressure following maximal exercise among different category of players and physical education students.

Material & Method

The study was conducted on 149 Punjabi University players preparing for inter university competition during their training camps held at Punjabi University, Patiala. The age range of the subjects was 18-25 years.

Mean characteristics of age, height & weight of the three groups are presented in table 1.

Table1: Comparison of mean values age, height & weight among different categories of players and PES

	N	Age, Yrs		Height, Cms		Weight, Kg	
		Mean	SD	Mean	SD	Mean	SD
Netball	29	20.52	0.78	1.78	0.08	35.86	5.01
Hand Ball	11	20.00	1.00	1.75	0.09	30.91	3.02
Boxers	25	22.24	2.03	1.69	0.06	31.20	3.62
Cyclists	21	20.33	1.98	1.75	0.05	32.14	4.05
Football	52	19.17	1.44	1.73	0.06	30.67	2.63
PES	11	22.36	2.25	1.76	0.08	40.91	5.39

Following cardiovascular parameters were measured in all the subjects at rest, during different progressive workloads and different stages of recovery.

- Heart rate in beats/min using Polar heart rate monitor
- Systolic & diastolic components of blood pressure by Auscultatory method using mercury sphygmomanometer & stethoscope

All the subjects were administered progressive workloads on an electrically controlled bicycle ergometer starting from 50W and the load was then increased in steps of 25W every minute until the exhaustion of the subject. Each subject was asked to maintain the pedaling frequency at 60 rpm. After exhaustion, the recovery

parameters in terms of heart rate and blood pressure were recorded at intervals of one minute for a total period of 15 minutes following maximal exercise. Keeping in view the room available in the journal for a research paper, it is not possible to depict the results of the study for all the workloads administered to the players; therefore the results have been compiled for selected workloads and described under the following sub headings:

- Heart rate & Blood pressure (BP) at rest
- Heart rate & BP response at 50W, 100W & 150W work loads
- Heart rate & BP response at 3rd, 9th and 15th minute of recovery following maximal exercise.

Results & Discussion:

1. Heart rate & Blood pressure (BP) at rest

Average resting heart rate ranged between 65.72 to 81.28 beats /minute among different categories of players' (table 2). Lowest average resting heart rate values have been observed, in case of boxers'. Statistically speaking there is a significant difference in resting heart rate values among different categories of players and physical education students as is indicated in tables 3-4.

Table 2: Comparison of mean Minute heart rate (MHR), systolic Blood Pressure (SBP) & diastolic Blood Pressure (DBP) at rest between different categories of players and Physical Education Students

		MHR, beats/min		SBP, mm Hg		DBP, mm Hg	
	N	Mean	SD	Mean	SD	Mean	SD
Netball	29	81.28	5.55	113.10	4.71	73.10	4.71
Hand Ball	11	74.18	5.10	115.36	5.55	73.64	5.05
Boxers	25	65.72	5.86	111.20	3.32	71.20	3.32
Cyclists	21	76.71	7.12	118.10	6.80	76.67	4.83
Football	52	70.73	6.97	113.37	4.92	73.27	4.74
PES	11	75.27	4.17	115.45	5.22	75.45	5.22

Table 3: ANOVA: Statistical comparison of resting MHR, SBP and DBP among different categories of players and PES

		Sum of Squares	df	Mean Square	F	Sig
MHR	Between Groups	3919.76	5	783.96	19.98	0
	Within Groups	5611.17	143	39.24		
	Total	9530.95	148			
SBP	Between Groups	635.20	5	127.04	5.01	0
	Within Groups	3625.83	143	25.36		
	Total	4261.03	148			
DBP	Between Groups	391.90	5	78.38	3.71	0.003
	Within Groups	3022.86	143	21.14		
	Total	3414.76	148			

Table 4: Scheffe Post hoc comparison for mean differences in resting MHR values among different categories of players and PES

	Handball	Boxers	Cyclists	Football	PES
Netball	7.09	15.56*	4.56	10.55*	6.00
Handball		8.46*	-2.53	3.45	-1.09
Boxers			-10.99*	-5.01	-9.55*
Cyclists				5.98*	1.44
Football					-4.54

Mean value of resting systolic and diastolic pressure among different categories of players and physical education students also reveal significant differences as evaluated by analysis of variance test (tables 3, 5 & 6). Cyclists are observed to posses' significantly higher resting systolic blood pressure in comparison to net ball players, boxers and football players. As far as the DBP is concerned, boxers are observed to possess lower value as compared to the cyclists.

Table 5: Scheffe Post hoc comparison for mean differences in resting SBP among different categories of players and PES

	Handball	Boxers	Cyclists	Football	PES
Netball	-2.26	1.90	-4.99*	-0.26	-2.35
Handball		4.16	-2.73	2.00	-0.09
Boxers			-6.90*	-2.17	-4.25
Cyclists				4.73*	2.64
Football					-2.09

Table 6: Scheffe Post hoc comparison for mean differences in resting DBP among different categories of players and PES

	Handball	Boxers	Cyclists	Football	PES
Netball	-0.53	1.90	-3.56	-0.17	-2.35
Handball		2.44	-3.03	0.37	-1.82
Boxers			-5.47*	-2.07	-4.25
Cyclists				3.40	1.21
Football					-2.19

2. MHR & BP response to exercise:

Administration of graded exercise is observed to reveal differential exercise heart rate & BP responses among the different categories of players. Boxers demonstrate significantly lower heart rate & SBP response than all the rest of categories of players at 50W workload. Among all other categories of players heart rate responses to 50W of workload is not found to be statistically different (Tables 7-9). Mean SBP response at this workload has been observed to be significantly lower in boxers than the cyclists while no statistical difference in SBP response is observed among other category of players. PES group also demonstrate significantly lower response in this variable as compared to the cyclists. Diastolic component of BP on an average recorded a decrease at 50W workload as compared to the average resting value recorded in the various categories. In statistical terms the DBP values are observed to be comparable among the different categories (Table 7, 8, & 11)

Table7: Comparison of MHR, SBP & DBP at 50W workload among different categories of players and PES

		MHR, beats/min		SBP, mm Hg		DBP, mm Hg	
	N	Mean	SD	Mean	SD	Mean	SD
Netball	29	147.69	7.78	149.31	7.99	59.93	3.87
Hand Ball	11	146.27	8.76	150.91	7.01	60.36	1.96
Boxers	25	135.08	7.34	146.00	6.46	58.96	2.80
Cyclists	21	144.33	4.65	155.24	9.81	59.48	4.31
Football	52	145.13	9.09	150.00	7.92	58.56	3.21
PES	11	146.27	4.43	143.64	5.05	60.55	3.70

Table 8: ANOVA: Statistical comparison of MHR, SBP and DBP at 50W workload among different categories of players and PES

		Sum of Squares	df	Mean Square	F	Sig
MHR	Between Groups	2566.86	5	513.37	8.54	0
	Within Groups	8595.14	143	60.11		
	Total	11162	148			
SBP	Between Groups	1411.64	5	282.33	4.66	0.00
	Within Groups	8655.47	143	60.53		
	Total	10067.11	148			
DBP	Between Groups	73.25	5	14.65	1.25	0.29
	Within Groups	1682.16	143	11.76		
	Total	1755.41	148			

Table 9: Scheffe Post hoc comparison for mean differences in MHR at 50W workload among different categories of players and PES

	Handball	Boxers	Cyclists	Football	PES
Netball	1.42	12.61*	3.36	2.56	1.42
Handball		11.19*	1.94	1.14	0.00
Boxers			-9.25*	-10.05*	-11.19*
Cyclists				-0.80	-1.94
Football					-1.14

Table 10: Scheffe Post hoc comparison for mean differences in SBP at 50W workload among different categories of players and PES

	Handball	Boxers	Cyclists	Football	PES
Netball	-1.60	3.31	-5.93	-0.69	5.67
Handball		4.91	-4.33	0.91	7.27
Boxers			-9.24*	-4.00	2.36
Cyclists				5.24	11.60*
Football					6.36

Cardiovascular reaction to further increase in exercise intensity to 100W reveals a similar response of heart rate as was observed at the starting workload of 50W. Boxers demonstrated a significantly lower value than the other groups (Table 11-13).

SBP responded significantly less vigorously in case of boxers than the other groups while DBP response to 100W workload was comparable in all the groups except for cyclists where it was found to be significantly lower (Tables 14 & 15).

Table 11: Comparison of MHR, systolic & diastolic BP at 100W among different categories of players and PES

		MHR, beats/min		SBP, mm Hg		DBP, mm Hg	
	N	Mean	SD	Mean	SD	Mean	SD
Netball	29	170.72	7.74	174.86	8.01	59.86	4.40
Hand Ball	11	171.09	8.30	179.64	4.57	60.36	5.12
Boxers	25	156.72	9.49	175.60	6.01	59.72	4.12
Cyclists	21	166.33	5.03	183.81	12.03	51.48	7.87
Football	52	168.25	8.66	178.37	6.40	54.79	4.41
PES	11	170.45	6.09	164.91	5.49	59.27	2.72

Table 12: ANOVA: Statistical comparison of MHR, 100W among different categories of players and PES

		Sum of Squares	df	Mean Square	F	Sig
MHR	Between Groups	3448.6	5	689.72	10.68	0
	Within Groups	9232.89	143	64.57		
	Total	12681.49	148			
SBP	Between Groups	2935.67	5	587.13	10.30	0
	Within Groups	8154.20	143	57.02		
	Total	11089.87	148			
DBP	Between Groups	1496.70	5	299.34	12.17	0
	Within Groups	3517.13	143	24.56		
	Total	5013.83	148			

Table 13: Scheffe Post hoc comparison for mean differences in MHR at 100W workload among different categories of players and PES

	Handball	Boxers	Cyclists	Football	PES
Netball	-0.37	14.00*	4.39	2.47	0.27
Handball		14.37*	4.76	2.84	0.64
Boxers			-9.61*	-11.53*	-13.73*
Cyclists				-1.92	-4.12
Football					-2.20

Table 14: Scheffe Post hoc comparison for mean differences in SBP at 100W workload among different categories of players and PES

	Handball	Boxers	Cyclists	Football	PES
Netball	-4.77	-0.74	-8.95*	-3.50	9.95*
Handball		4.04	-4.17	1.27	14.73*
Boxers			-8.21*	-2.77	10.69*
Cyclists				5.44	18.90*
Football					13.46*

Table 15: Scheffe categories Post hoc comparison for mean differences in DBP at 100W workload among different categories of players and PES

	Handball	Boxers	Cyclists	Football	PES
Netball	-0.50	0.14	8.39*	5.58*	1.09
Handball		0.64	8.89*	5.58*	1.09
Boxers			8.24*	4.93*	0.45
Cyclists				-3.31	-7.79*
Football					-4.48

Comparison of minute heart rate response to 150W workload between different groups divulged significantly lower response in case of boxers than the other groups. Physical education students' group recorded the highest mean minute heart rate value that is significantly more than the mean MHR of boxers, cyclists and footballers (Tables 17-19).

Systolic blood pressure response to 150W workload brought out maximal reaction from cyclists followed by handball, football, boxers, netball & PES in decreasing order. In statistical terms, significant differences have been recorded in systolic blood pressure response among the different categories (Table 19).

Table 16: Comparison of minute heart rate, SBP & DBP at 150W workload among different categories of players and PES

		MHR, beats/min		SBP, mm Hg		DBP, mm Hg	
	N	Mean	SD	Mean	SD	Mean	SD
Netball	29	186.17	6.23	196.79	5.61	60.55	3.89
Hand Ball	11	184.09	6.06	201.45	5.15	60.18	2.09
Boxers	25	170.28	12.43	198.80	4.15	58.84	3.48
Cyclists	21	183.10	6.07	209.81	16.60	46.19	11.08
Football	52	181.29	9.41	200.98	4.72	54.00	5.36
PES	11	193.18	6.15	186.55	7.63	59.81	4.04

Table 17: ANOVA: Statistical comparison of MHR, SBP & DBP at 150W workload among different categories of players and PES

		Sum of Squares	df	Mean Square	F	Sig
MHR	Between Groups	5403.06	5	1080.61	14.32	0
	Within Groups	10792.21	143	75.47		
	Total	16195.26	148			
SBP	Between Groups	4419.54	5	883.91	14.38	0
	Within Groups	8788.43	143	61.46		
	Total	13207.97	148			
DBP	Between Groups	3381.53	5	676.31	19.98	0
	Within Groups	4841.04	143	33.85		
	Total	8222.58	148			

Table 18: Scheffe Post hoc comparison for mean differences in MHR at 150W workload among different categories of players and PES

	Handball	Boxers	Cyclists	Football	PES
Netball	2.08	15.89*	3.08	4.88	-7.01
Handball		13.81*	1.00	2.80	-9.09
Boxers			-12.82*	-11.01*	-22.90*
Cyclists				1.81	-10.09
Football					-11.89*

Table 19: Scheffe Post hoc comparison for mean differences in SBP at 150W workload among different categories of players and PES

	Handball	Boxers	Cyclists	Football	PES
Netball	-4.66	-2.01	-13.02*	-4.19	10.25*
Handball		2.65	-8.36	0.47	14.91*
Boxers			-11.01*	-2.18	12.25*
Cyclists				8.83	23.26*
Football					14.44*

In a similar way DBP also has been observed to respond to varying degrees among the various groups. Cyclists, boxers & footballers exhibit significantly lower DBP values as compared to the other groups (Table 20).

Table 20: Schaeffe Post hoc comparison for mean differences in DBP at 150W workload among different categories of players and PES

	Handball	Boxers	Cyclists	Football	PES
Netball	0.37	1.71	14.36*	6.55*	0.73
Handball		1.34	13.99*	6.18	0.36
Boxers			12.65*	4.84*	-0.98
Cyclists				-7.81*	-13.63*
Football					-5.82

3. Heart rate & Blood pressure (BP) recovery following maximal exercise:

Comparison of initial recuperation in heart rate following exhaustive exercise as measured at the third minute of recovery among the various groups demonstrate lowest mean MHR value of 101.81 beats/min in case of cyclists followed by boxers (103.44), handball (105.73), football (106.08), netball (112.21) and PES (118.55) in increasing order. In other words cyclists, boxers & football group of players are observed to recover relatively more quickly as compared to the other groups (Tables 21-23). Statistically speaking significant differences are observed in the 3rd minute of recovery period in the minute heart rate values among the various groups.

Table 21: Comparison of 3rd minute recovery MHR values among different categories of players and PES

		MHR, beats/min		SBP, mm Hg		DBP, mm Hg	
	N	Mean	SD	Mean	SD	Mean	SD
Netball	29	112.21	6.37	131.21	6.77	60.48	3.88
Hand Ball	11	105.73	2.53	122.73	4.67	60.36	4.37
Boxers	25	103.44	8.43	125.20	8.95	62.72	5.22
Cyclists	21	101.81	8.37	126.43	7.93	63.24	5.64
Football	52	106.08	5.97	126.63	7.19	61.69	5.39
PES	11	118.55	7.17	136.82	7.17	59.36	3.17

Table 22: ANOVA: Statistical comparison of MHR, SBP & DBP at 3rd minute of recovery among different categories of players and PES

		Sum of Squares	df	Mean Square	F	Sig
MHR	Between Groups	3195.07	5	639.01	13.769	0
	Within Groups	6636.76	143	46.41		
	Total	9831.83	148			
SBP	Between Groups	1792.38	5	358.48	6.545	0
	Within Groups	7831.78	143	54.77		
	Total	9624.16	148			
DBP	Between Groups	196.10	5	39.22	3.249	0.16
	Within Groups	3484.26	143	24.37		
	Total	3680.36	148			

Table 23: Scheffe Post hoc comparison for mean differences in 3rd minute recovery heart rate among different categories of players and PES

	Handball	Boxers	Cyclists	Football	PES
Netball	**6.48**	**8.77***	**10.40***	**6.13***	**-6.34**
Handball		**2.29**	**3.92**	**-0.35**	**-12.82***
Boxers			**1.63**	**-2.64**	**-15.11***
Cyclists				**-4.27**	**-16.74***
Football					**-12.47***

SBP at 3rd minute of recovery following maximal exercise reveal higher values in case of netball group and PES as compared to the other groups. In statistical terms the cyclists, boxers, football & handball players record significantly lower SBP values than the netball & PES groups (Table 24). Systolic pressure in other words exhibit a tendency to return to the resting state faster in case of cyclists, boxers, football & handball players than the netball & PES groups.

Table 24: Scheffe Post hoc comparison for mean differences in 3rd minute recovery SBP among different categories of players and PES

	Handball	Boxers	Cyclists	Football	PES
Netball	**8.48**	**6.01**	**4.78**	**4.57**	**-5.61**
Handball		**-2.47**	**-3.70**	**-3.91**	**-14.09***
Boxers			**-1.23**	**-1.43**	**-11.62***
Cyclists				**-0.21**	**-10.39***
Football					**-10.18***

DBP recovery after three minutes of cessation of maximal exercise reveals almost comparable values (Table 21). Statistically speaking no significant differences have been observed (Table 22).

Progression of recovery period to nine minutes following maximal exercise reveals a further decline in the average values of MHR recorded in the various groups (Table 25). Cyclists, boxers & football players exhibit the same trend of quicker recovery than their other counterparts as was observed at 3rd minute of recuperation. Analysis of variance reveal existence of significant differences in MHR recorded at 9th minute of recovery (Table 26). Scheffe post hoc comparison further reveals that cyclists, boxers & football players recover significantly quickly than PES group (Table 27).

Table 25: Comparison of 9th minute recovery MHR, SBP & DBP values among different categories of players and PES

		MHR, beats/min		SBP, mm Hg		DBP, mm Hg	
	N	Mean	SD	Mean	SD	Mean	SD
Netball	**29**	**100.97**	**4.90**	**116.21**	**4.75**	**73.79**	**4.94**
Hand Ball	**11**	**97.27**	**2.10**	**113.64**	**5.05**	**72.73**	**4.67**
Boxers	**25**	**94.52**	**5.45**	**114.40**	**5.07**	**72.00**	**5.00**
Cyclists	**21**	**92.76**	**6.25**	**117.86**	**6.04**	**76.67**	**4.83**
Football	**52**	**95.98**	**4.79**	**114.04**	**6.03**	**73.08**	**5.44**
PES	**11**	**106.27**	**6.33**	**124.36**	**5.43**	**70.91**	**3.02**

Table 26: ANOVA: Statistical comparison of MHR, SBP & DBP at 9th minute of recovery among different categories of players and PES

		Sum of Squares	df	Mean Square	F	Sig
MHR	**Between Groups**	**1985.92**	**5**	**397.18**	**15.02**	**0**
	Within Groups	**3780.36**	**143**	**26.44**		
	Total	**5766.28**	**148**			
SBP	**Between Groups**	**1162.21**	**5**	**232.44**	**7.59**	**0**
	Within Groups	**4378.34**	**143**	**30.62**		
	Total	**5540.55**	**148**			
DBP	**Between Groups**	**355.94**	**5**	**71.19**	**2.85**	**0.02**
	Within Groups	**3566.21**	**143**	**24.94**		
	Total	**3922.15**	**148**			

Table 27: Scheffe Post hoc comparison for mean differences in 9th minute recovery MHR among different categories of players and PES

	Handball	Boxers	Cyclists	Football	PES
Netball	**3.69**	**6.45***	**8.20***	**4.98***	**-5.31**
Handball		**2.75**	**4.51**	**1.29**	**-9.00***
Boxers			**1.76**	**-1.46**	**-11.75***
Cyclists				**-3.22**	**-13.51***
Football					**-10.29***

SBP tends to attain almost similar average values at 9th minute of recovery in the various groups except in the case of

PES group where relatively higher mean value of 124.36 mm Hg is observed. In statistical terms, it is found to be significantly greater than all the other groups (Tables 25, 26 & 28).

Table 28: Scheffe Post hoc comparison for mean differences in 9th minute recovery SBP among different categories of players and PES

	Handball	Boxers	Cyclists	Football	PES
Netball	2.57	1.81	-1.65	2.17	-8.16*
Handball		-0.76	-4.22	-0.40	-10.73*
Boxers			-3.46	0.36	-9.96*
Cyclists				3.82	-6.51
Football					-10.33*

DBP recovery at 9th minute of cessation of maximal exercise reveals almost comparable values (Table 25). Statistically speaking no significant differences have been observed among the different groups (Table 26).

Cardiovascular restoration to further advancement in recovery to 15th minute demonstrates a continuous decrease in minute heart rate though at a slower rate. The picture is similar to that observed at 3rd & 9th minute of recovery phases. PES group is observed to recover slowest of the all other groups (Table 29 - 31).

Table 29: Comparison of 15th minute recovery MHR, SBP & DBP values among different categories of players and PES

		MHR, beats/min		SBP, mm Hg		DBP, mm Hg	
	N	Mean	SD	Mean	SD	Mean	SD
Netball	29	93.93	3.91	109.31	5.30	73.45	4.84
Hand Ball	11	92.55	1.75	104.55	5.22	73.64	5.05
Boxers	25	87.44	4.90	103.60	4.68	72.40	4.36
Cyclists	21	88.10	4.57	108.81	6.31	76.67	4.83
Football	52	91.52	3.98	104.13	4.82	73.46	4.80
PES	11	100.91	6.20	114.55	5.22	73.64	5.04

Table 30: ANOVA: Statistical comparison of MHR, SBP & DBP at 15th minute of recovery among different categories of players and PES

		Sum of Squares	df	Mean Square	F	Sig
MHR	**Between Groups**	1811.58	5	362.32	19.58	0
	Within Groups	2646.45	143	18.51		
	Total	4458.03	148			
SBP	**Between Groups**	1596.28	5	319.26	11.89	0
	Within Groups	3838.96	143	26.85		
	Total	5435.24	148			
DBP	**Between Groups**	231.45	5	46.29	2.03	0.08
	Within Groups	3263.85	143	22.82		
	Total	3495.30	148			

Table 31: Scheffe Post hoc comparison for mean differences in 15th minute recovery MHR among different categories of players and PES

	Handball	Boxers	Cyclists	Football	PES
Netball	1.39	6.49*	5.84*	2.41	-6.98*
Handball		5.11	4.45	1.03	-8.36*
Boxers			-0.66	-4.08*	-13.47*
Cyclists				-3.42	-12.81*
Football					-9.39*

Systolic component of blood pressure continues to drop in all the groups and is observed to even fall below the resting levels. Inter group differences are however observed in the SBP and have statistical significance also. PES group demonstrate significantly greater mean value of SBP than the other groups (Table 32). DBP on the other hand show similar values and are statistically not different from each other.

Table 32: Scheffe Post hoc comparison for mean differences in 15th minute recovery SBP among different categories of players and PES

	Handball	Boxers	Cyclists	Football	PES
Netball	4.76*	5.71*	0.50	5.18*	-5.24
Handball		0.95	-4.26	0.41	-10.00*
Boxers			-5.21*	-0.53	-10.95*
Cyclists				4.67	-5.74*
Football					-10.41*

In present investigation systolic BP response in relationship to HR during exercise and recovery has also been

studied, it is observed from the figures that blood pressure increases with increase in MHR during graded exercise in all categories of players.

It is interesting to observe that BP response to exercise in relation to HR is mild up to acceleration of HR to the order of 150 beat/minute, where after BP increases more vigorously. In other words slope of BP-HR response during exercise leading to increase in HR upto 150 beat/minute is observed to be less steep as compared to BP response beyond 150 beat/minute.

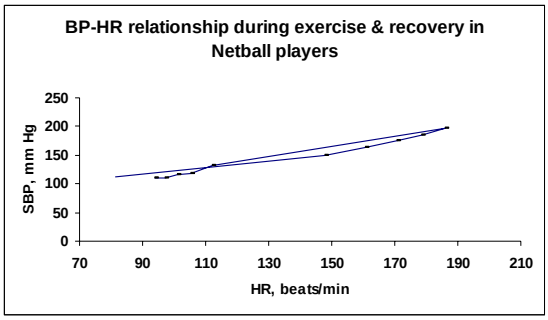

Figure 1

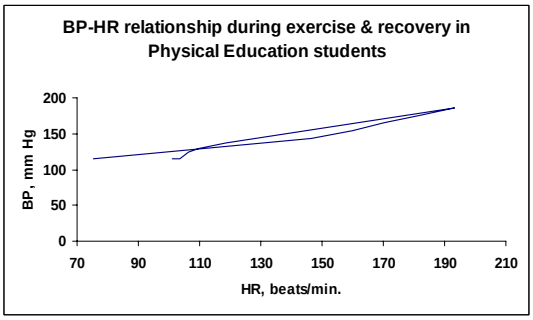

Figure 2

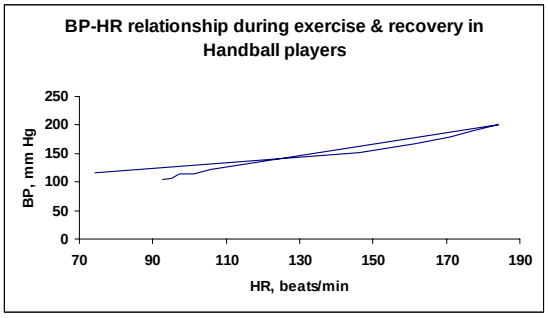

Figure 3

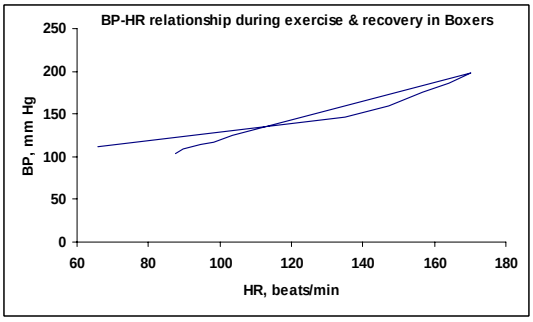

Figure 4

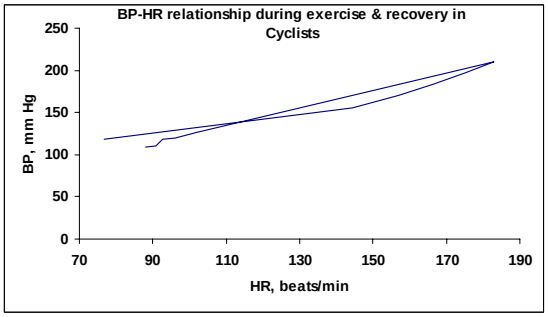

Figure 5

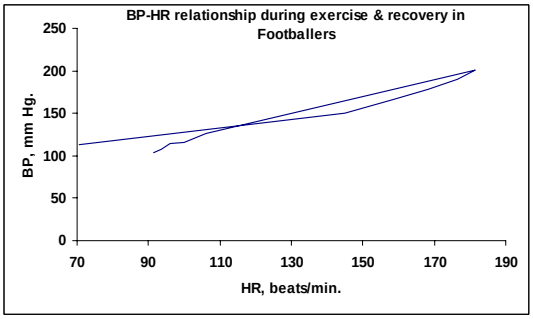

Figure 6

Boxers, cyclists and football players exhibit steeper BP-HR response after achieving 150 beat/minute of HR as compared to other categories. The observation suggests more intensive sympathetic stimulation attained by

boxers, cyclists and footballers beyond 150 beats/min of exercise. This stimulation helps them to achieve higher cardiac output and thus increases their ability to do exercise. Cardiac output increases in a rectilinear fashion and plateaus at maximal exercise. The initial increase in cardiac output reflects an increase in stroke volume and heart rate; however, at work load greater than 40-50% VO_2max, the increase in cardiac output is achieved solely by increases in the heart rate. In normally active individuals stroke volume increases initially and then plateaus at approximately 40-50% of VO_2max (*Astrand et al, 1964 and Higginbotham et al, 1986*). Stroke volume may actually decrease slightly near the end of maximal exercise in untrained and moderately trained individual (*Gledhill and Jamnik, 1994*). Left ventricular end-diastolic volume increases largely because of the return of blood to the heart by the active muscle pump and the increased sympathetic out flow to the veins causing vasoconstriction and augmenting venous return. Left ventricular end-systolic volume decrease because of augmented contractility of the heart, which eject more blood from the ventricle and leaves less in the ventricle (*Poliner et al, 1980*).

Heart rate increases in rectilinear fashion and plateaus at maximal exercise. Systolic blood pressure increases during maximal exercise, often reaching values in exercise of 200 mmHg in very fit individuals. The increase in systolic blood pressure is caused by the increased cardiac output which out weighs the decrease in resistance. Systolic blood pressure and heart rate are two variables that are routinely monitored during an exercise test to ensure the safety of participants. If either of these variables fails to rise with an increasing workload, cardiovascular insufficiency and an inability to adequately profuse tissue is possibility.

Another interesting observation indicates that BP-HR relationship line does not tow the BP-HR relationship line observed during exercise. The BP-HR relationship line during recovery is observed to lie above the BP-HR relationship line of exercise during the first minute of recovery indicating that BP remained elevated in spite of the fact that HR recorded a tremendous drop during the first minute of recovery, after this the BP-HR relationship line during recovery is observed to lie below the exercise BP-HR line. The abrupt drop in heart rate during first minute of recovery can be explained on the findings of many researchers who have reported withdrawal of intensive sympathetic stimulation achieved during exercise *(Gaesser and Brooks, 1984 and. Zafeiridis et al, 2005).*

Conclusion

On the basis of the study it is concluded that significant differences are demonstrated by different category of players and physical education students in their blood pressure and heart rate responses to varying intensities of exercise and at different points of recovery.

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