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Original Article:

Effect of Wheelchair Running on Recovery of Blood Lactate and Physical Performance after High-Intensity Intermittent Exercise – An Experimental Trial

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Abstract: Background and Purpose: Repetitive sprint sport players perform high intensity exercise only for a small percentage of a total game and such periods are often instrumental in determining the eventual outcome. Recovery is a key factor for performance, and constant lack of recovery or insufficient recovery turns into overtraining which is detrimental in achieving peak performance. The purpose was to find out the effect of wheelchair running on the physical performance recovery after high-intensity intermittent exercise. **Method:** Ten sportsmen having the age range from 20 to 29, VO2max Ranges from 60.51 to 64.29 were randomly divided into experimental and control groups. After filling pre-participation questionnaire and 30-min of supine rest, Blood lactate and the field tests for the measurement of static balance, power, speed and agility were applied. The subjects were made to run in the treadmill and to increase the intensity to reach the Target Heart Rate (THR). After 1-min the subjects were given rest for 15-s and after that they started exercise again and thus the subjects completed several bouts of such exercises until exhaustion followed by either Passive rest or wheelchair running for the duration of 10 minutes. Parameters were measures after completed the exercise bout and after the recovery. **Results:** After the recovery in experimental group significant improvement found only in blood lactate ($p<0.01$) and no significant changes found in other parameters while in control group no significant changes found in all parameters. There was no significant difference found in all the parameters including blood lactate between the groups. **Conclusion:** Both wheelchair running and passive recovery are same in the efficiency of blood lactate removal and restoration of physical performance following intense intermittent exercise.

Key Words: Blood lactate; Wheelchair running; Recovery; Physical performance.

Introduction:

High intensity exercise can be performed continuously only for a short period of time and energy demand fluctuate from a high to low level between the work and rest periods. Work of high intensity that it can be performed continuously only for a short period of time is accompanied by a high rate of glycogen depletion, lactate accumulation and a greater contribution of carbohydrate to oxidative metabolism.(1) However, when work of an equally high workload is performed with introduction of the rest periods in between the work periods, it can be sustained for an extensive period of time and energy demand fluctuates from a high to low level between the work and rest periods.(2) The lactate formed in fast twitch muscle fibers can diffuse out of the muscle and enter the blood or it can shuttle directly to adjacent slow twitch muscle fibers where the lactate can be consumed as a fuel. Blood lactate levels can be used to guide training intensity because effective training occurs when an individual trains at an exercise intensity that corresponds to the lactate threshold i.e. the exercise intensity at which lactate begins to build up in the blood.(3,4)

Performance hindering muscular fatigue experienced during exercise is often associated with high tissue concentrations of lactic acid.(5) Factors that could increase the rate of lactic acid production include, increased activity of lactate dehydrogenase (due to increased activity of fast- twitch muscle fibers); increased concentration of pyruvate in the cytoplasm (due to the failure of the Krebs cycle to keep pace with glycolytic production of pyruvate); or increased concentration of hydrogen atoms carried as NADH + H+ (due to a failure of the hydrogen shuttle system to keep pace with glycolytic production of hydrogen atoms). With this accumulation of lactic acid there is a corresponding increase in hydrogen ion concentration that inhibits glycolytic reaction by inhibiting the activity of glycolytic enzymes like lactate dehydrogenase and phosphofructokinase and interferes with excitation-contraction-coupling and cross bridge formation.(6) These effects combine to decrease the available energy and muscle contractile force during subsequent exercise. So lactate removal from the blood following exercise therefore appears to be of great importance in improving the subsequent performance particularly when the exercise is repeated at high intensity.(7)

Recovery encompasses active process of re-establishing physiological and psychological resources and states that allow the individual to use these resources again.(8) A return to pre-exercise levels of blood lactate usually occurs within an hour and light activity during the post-exercise period has been shown to accelerate this clearance.(9-10) The recovery strategies are designed to maintain a high rate of blood flow to the working muscles, to expedite lactic acid translocation from the muscle cell to the blood, to accelerate the resynthesis of high energy phosphate, and to replenish oxygen in the blood, bodily fluids and muscle myoglobin. The recovery should be sufficiently long enough to allow the next repetition to be at the same or above the level as the previous effort, but a longer recovery should be avoided if optimum training benefit is to result. As a rule of thumb, the heart rate should drop to approximately 120-bpm near to the end of the recovery interval. (11) During active recovery, increase in muscle blood flow, enhances lactate exchange from active muscles to removal sites and increase the lactate oxidation, which has been described as the major pathway of lactate metabolism.(12) So the lactic acid does not have a chance to accumulate in the muscles.(13)

Recovery from strenuous exercise is less understood but extremely important for the athletes. While the lower limb weight bearing is not allowed even for the activities for daily living, wheelchair locomotion can be used as a tool to maintain strength in upper body to maintain central endurance and to prevent other complications of detraining. As well as it can be used as a method of recovery from high level work bouts of lower limb. So for very few studies have been conducted to examine the effect of wheelchair running on the recovery following exhaustive bouts of intermittent exercises. Therefore the present study aims at examining the effect of wheelchair running on the recovery from an exhaustive bout of intermittent exercises. It is hypothesized that there will be significant difference between wheelchair running as an active recovery tool and passive recovery in enhancing the recovery after the high intensity intermittent exercises. The objectives were,

- To determine the effects of passive recovery on the recovery of field test parameters and Blood lactate.
- To determine the effects of wheelchair running on the recovery of Blood lactate and field test parameters.
- To compare the effects of passive recovery and wheelchair running on the recovery of field test parameters and blood lactate.

Design and Methodology:

Subjects: This experimental research consisted of 10 sportsmen having the age: 24.9 ± 2.47 years (range 20-29], height: 169.4 ± 4.1 cms (range 160-176), weight: 69 ± 5.53 kgms (60-78), VO2max: 62.41± 0.99 ml/kg/min (range 60.51- 64.29) were randomly divided into two equal groups. Subjects were university sports players from Guru Nanak Dev University, Amritsar, India. All the subjects were informed of the nature, purpose and parameters of the study before giving their voluntary consent to participate in this study 3 days prior to the actual experiment. Only male athletes and players with minimum 3 years of sports training and with the maximal oxygen uptake more than 60 ml/kg/min were included in the study. Subjects with any musculoskeletal pain, recent injury, undergoing any medications or having any cardio-respiratory difficulties were excluded from the study.

Materials: A pre-participation questionnaire was used to select the subjects to fulfill the inclusion and exclusion criteria based on which the subjects were selected. A Lactate Analyzer (Analox – PLM5 Portable) with the set of capillaries for collection of blood samples, POLAR short range heart rate telemetry (POLAR S410TM), Non-motorized treadmill, Wheelchair, Stopwatch, Metronome, Wooden stepping bench of 16.25" height, Measuring tape were used for data collection.

Experimental protocol: The subjects attended pre-participation screening phase 3-days prior to the actual experiment in which they were asked to fill the screening questionnaire. Maximal oxygen uptake (VO2max) of the each subject was measured on the same day of screening, using Queen's college step test.(14) On the day of the experiment the subjects after 8 – 9 hours of prior meal, came to the department where the experiment was conducted. After 30-min of supine rest, Blood lactate concentration was measured with the subjects in supine position and the field tests including Stork Stand test(15), Vertical jump test(16), 50-yard sprint test(17), and 10-yard shuttle run test(17) for the measurement of static balance, power, speed and agility were applied according to the previously described guidelines. All these values were noted as the baseline values (Pre-exercise values).

Then the subjects were made to run in the treadmill with wearing the POLAR short-range telemetry strap on the chest and the monitoring watch in their wrist. The subjects were asked to increase the intensity of running such a way they should reach the Target Heart Rate (THR). After 1-min the subjects were given rest for 15-s and after that period of rest subjects started exercise again to reach the THR. Thus the subjects completed several bouts of such exercises until exhaustion. After the exercise bout all the exercise parameters were measured and the values were recorded as Post- exercise values.

Then the subjects were then randomly assigned to go to the recovery either Passive rest or wheelchair running on level tar road for the duration of 10 minutes. During the wheelchair running, heart rate was monitored continuously to not to exceed the calculated 40% HRmax. Immediately after the recovery all the parameters were measured (Post-recovery values).

Statistical Analysis: Descriptive statistics was used to calculate the mean, Standard deviation and standard error for the purpose of summarizing the data and for further analysis for the difference between the groups. Paired samples t test was used to compare the within group effectiveness between the pre test and the post test measurements. To compare the effectiveness between the groups independent sample t test were used. The p level was kept as 0.05 and less than that level was considered as significant. All data were analyzed using SPSS 11.5 software.

Results:

All the subjects completed the experiment successfully and the collected data were tabulated and assessed statistically. In the experimental group after the recovery no significant increase was observed in all the parameters except the Stork stand where significant increase ($p<0.05$) and in blood lactate where highly significant decrease ($p<0.01$) were found (Table 1). The mean post-recovery values for Stork stand, Jump, Sprint, Shuttle run and Blood lactate values are 17.18-s, 29.82cms, 7.40-s, 10.29-s and 7.0mmol/l, while post-exercise mean values for the same are 9.62-s, 29cms, 7.87-s, 11.69-s and 11.8mmol/l, respectively. The overall percentage improvement of post-recovery Stork stand, Vertical jump, Sprint, and Shuttle run performance are 78.6%, 2.8%, 6%, 12% respectively and 40.7% decrease in Blood lactate.

Table 1: Intra-group comparison of parameters between post-exercise and post recovery in experimental group.

Parameters	Post-exercise			Post-recovery			% Change	\`t' value	P level
	Mean	S.D	S.E	Mean	S.D	S.E			
Stork stand (Secs)	9.62	3.64	1.63	17.18	5.88	2.63	78.6↑	2.45	< 0.05
Vertical jump (Cms)	29.0	6.10	2.73	29.82	6.07	2.72	2.8↑	0.21	NS
Sprint (Secs)	7.87	0.54	0.24	7.40	0.66	0.29	6.0↑	1.23	NS
Shuttle run (Secs)	11.69	1.66	0.74	10.29	0.71	0.32	12↑	1.74	NS
Blood lactate (mmol/l)	11.8	2.23	1.0	7.0	1.44	0.64	40.7↓	4.05	< 0.01

NS - Non-significant, ↑ - increased, ↓ - decreased

In control group also after the recovery no significant increase was observed in all the parameters including Blood lactate (Table 2). The mean post-recovery values for Stork stand, Jump, Sprint, Shuttle run and Blood lactate values are 16.74-s, 34.3cms, 7.21-s, and 11.02-s, 7.76mmol/l, respectively while post-exercise mean values are 9.49, 33.3, 7.57, 10.67and 10.06mmol/l respectively. The respective percentage of increased post-recovery mean values for Stork stand, Vertical jump, Sprint, and Shuttle run were 76.4%, 3%, 5%, and 3.3%, respectively and 22.9% decrease in Blood lactate.

Table 2: Intra-group comparison of field test parameters between post-exercise and post recovery in control group.									
Parameters	Post-exercise			Post-recovery			% Change	`t' value	P Level
	Mean	S.D	S.E	Mean	S.D	S.E			
Stork stand (Secs)	9.49	5.68	2.54	16.74	12.48	5.58	76.4 ↑	1.18	NS
Vertical jump (Cms)	33.3	10.07	4.50	34.3	9.71	4.34	3↑	0.16	NS
Sprint (Secs)	7.57	0.52	0.23	7.21	0.38	0.17	4.8 ↑	1.25	NS
Shuttle run (Secs)	10.67	0.56	0.25	11.02	0.98	0.44	3.3 ¯	0.67	NS
Blood lactate (mmol/l)	10.06	2.25	1.01	7.76	2.70	1.21	22.9 ¯	1.46	NS

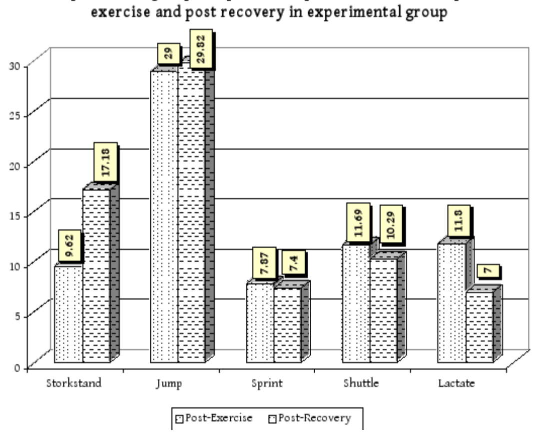
NS - Non-significant, ↑ - increased, ¯-decreased

In comparison of post-recovery field test and Blood lactate parameters between experimental and control groups the result showed no significant difference in all the parameters between the two groups (Table 3).

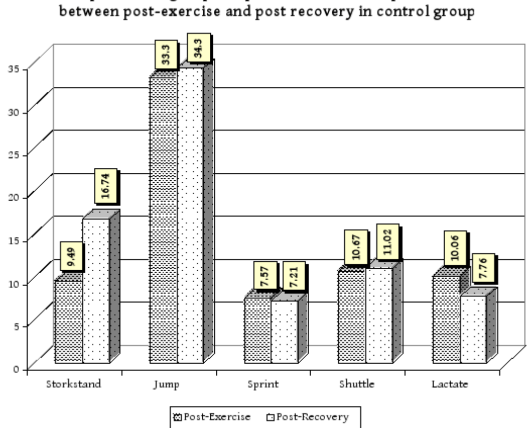
Table 3: Inter-group comparison of post-recovery values between experimental and control group.								
Parameters	Experimental			Control			`t' value	P level
	Mean	S.D	S.E	Mean	S.D	S.E		
Stork Stand	17.18	5.88	2.63	16.74	12.48	5.58	0.07	NS
Vertical jump	29.82	6.07	2.72	34.3	9.71	4.37	0.87	NS
Sprint	7.4	0.66	0.29	7.21	0.38	0.17	0.57	NS
Shuttle run	10.29	0.71	0.32	11.02	0.98	0.44	1.34	NS
Blood lactate (mmol/l)	7.0	1.44	0.64	7.76	2.7	1.21	0.56	NS

NS - Non-significant

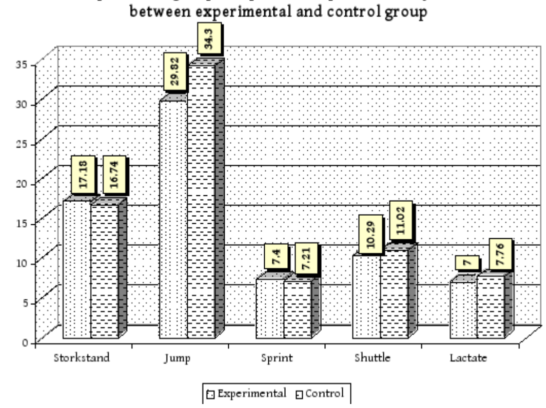
Graph 1: Intra-group comparison of parameters between post-exercise and post recovery in experimental group



Graph 2: Intra-group comparison of field test parameters between post-exercise and post recovery in control group



Graph 3: Intergroup comparison of post-recovery values between experimental and control group



Discussion:

During exercise, particularly short-term high intensity exercise, muscles produce lactate rapidly, whereas lactate clearance is slowed. Later during recovery from short- term exercise, there is net lactate uptake from the blood by resting muscles or other muscles that are doing mild to moderate exercise.(18) The ability to maintain a high power output during high-intensity intermittent exercise was impaired when oxygen availability was reduced by acute hypoxia, which was associated with a higher accumulation of blood lactate.(19) Therefore, lactic acid removal after exercise had been considered critical for the resumption of exercise, especially during athletic competition involving repetitive high-intensity activities. Since it has been suggested that muscles engaged in heavy exercise will negatively affect the performance in other non-exercised muscles(20), the use of non-maximally exercised muscles during active recovery of low-intensity i.e. below the lactate threshold theoretically could be beneficial on the subsequent repeated performances of the maximally exercised muscle groups.

In this study blood lactate significantly increased ($p<0.001$) in both the groups after the exercise from the resting level to the mean increase of 9.48 ± 2.67mmol/l (WC) and 8.70 ± 2.16 mol/l (PR). Ferrauti et al.(21) also found significant elevation of BLC (9.04 ± 3.06mmol/l, $p<0.01$) after intermittent sprint running training in tennis players. Various authors reported that light aerobic work during recovery below the anaerobic threshold, maintain an elevated state of metabolism and substrate utilization by the active tissues, results in faster decrease in lactate concentration and acidity in muscle and blood.(22-26) In this study the blood lactate after 10 min of recovery decreased from the resting level significantly ($p<0.001$) in WC group [mean value 4.8 ± 2.08mmol/l], while no significant decrease was observed in PR group [mean reduction, 3.22 ± 2.1mmol/l]. The reason for blood lactate reduction after wheelchair running recovery is the increased rate of metabolic clearance during exercise than compared to the rest during recovery. But statistically no significant difference in lactate reduction was found between the WC and PR groups. during passive recovery the lactate is not needed as fuel and could therefore contribute to the resynthesis of glycogen which takes longer time, whereby the reason for the non-significant decrease in wheelchair running than the passive recovery may be due to the fact that recovery exercises performed by the muscles other than those that were fatigued could have led a arterial hypotension through plasma fluid loss and additional vasodilatation depending on the muscle mass involved.(27) Active arm recovery might have also caused vasoconstriction in resting lactacid muscles leading to a slower release of lactate. Baker and King (28) reported that low-intensity leg exercise to be more effective in promoting lactate clearance during a 30-min recovery period after exhaustive arm exercise than either passive recovery or low-intensity arm exercise and no significant difference in lactate clearance was reported between the arm exercise and rest [mean value, 4.3 ± 0.8(arm), 5.6 ± 1.6(rest)]. But here the high-intensity exercise mode and active arm recovery mode were same type of exercise in contrast to the present study methodology.

Balance, power, speed and agility are necessary in delivering the sports performance. The quality i.e. the movement pattern and coordination of specific actions in the sports games are largely dependent on the physiological strain produced during short-term intermittent exercise.(21) It was speculated that elevated levels of blood lactate should have an adverse effect on muscle function.(29) In addition, several studies had suggested that work performance is adversely affected by elevated levels of lactate (7,30) and the accumulation of H+, inorganic phosphate and H2PO4- in the muscle cell may directly impair the activation of the contractile mechanism.(31) Increased accumulation of the lactate which result in fatigue of the muscles lead to a decreased ability to generate powerful contraction and reduced proprioceptive impulses of fatigued muscles due to depletion of energy sources and fluid loss result in decreased balance and coordination. After 10 min of recovery balance timing was improved significantly ($p<0.05$) in WC group with the mean timing difference of 8.25 ± 7.74-s while no significant difference was noted in PR group (mean timing difference, 7.25 ± 7.57-s). This may be due to the psychological benefits from active recovery that most of the athletes want to be active to taper off the exercise.(32) But no significant difference in the improvement after recovery between the groups shows that the effect of passive and wheelchair running recovery modalities are same in preserving the performance after the high intensity intermittent exercise.

Testing the jumping ability measure the ability to expend maximum energy in one explosive act, projecting the body through the space. We used the vertical jump test described by Texas Governor's Commission. Some studies associated the decreased lactate levels through active recovery, with a corresponding increase in power output, than compared with passive recovery.(7,33) But it had been stated that reduction in muscular power during intermittent running and cycling was related to the increase of blood lactate concentration (34) and PCr resynthesis rate.(35) after the recovery vertical jump performance had not improved significantly in both the groups [mean differences were 1.42 ± 1.06cms (WC), and 1.0 ± 1.41cms (PR)] in this study moreover there was no significant difference between the groups, indicates no beneficial effect of wheelchair running recovery than passive recovery regarding the preservation of power output after the intense exercise. Therefore the lack of deterioration in muscle function in relation to increased BLC may be in part attributed to the non-linear relationship between intramuscular pH and blood lactate. Similar findings were reported by (36,37) who found no difference in maximal effort exercise following 20min of either active or passive recovery with a blood lactate varying from 5-12mM prior to the next performance.

The result of the 50yard sprint also showed no significant decrease after the supramaximal exercise bouts (mean reduction difference were, 0.28 ± 0.1-s for WC, and 0.49 ± 0.35-s for PR). After the 10min of recovery also there is no significant increase in the sprint performance in both the groups (mean difference were, 0.48 ± 0.57-s for WC, and 0.38 ± 0.39-s for PR) in accordance with the previous findings (30) stated that unaffected subsequent muscle function after the recovery modes. This indicates the no difference of the wheelchair running recovery ahead of the passive recovery in improving the motor ability of the athletes after the high-intensity intermittent exercise. Additionally, results of this study may reflect other possible consequences of a fall in muscle pH, such as an impairment of muscle mechanical function (29) or a negative influence on central nervous activation.(38)

Shuttle run performance, another field test of agility also shows no significant decrease after the exercise bout from the resting values in both groups (mean difference in the timing, 0.91 ± 0.69-s for WC group, and 0.19 ± 0.10-s for PR group), but the reduction in performance shows significant difference ($p<0.05$) between the two groups i.e. it was reduced a 2.5% in WC group and a 1.7% in PR group. After the recovery, both groups showed significant difference ($p<0.05$) in improvement of shuttle run performance (mean difference were, 1.4 ± 1.06-s in WC group, and 3.48 ± 1.54-s in PR group) in which the post-recovery shuttle run performance improvement was 12% more than the resting levels in WC group while in PR group it was 3.3% less than the resting level. This indicates that wheelchair running recovery have improved the shuttle run performance than the passive recovery. The reason for the improved shuttle run in our study after wheelchair running may be due to the better elimination of lactate and better psychological recovery than passive recovery.

Overall no difference in enhancing recovery from high intensity intermittent exercise and the preservation or improving all the field test performance except in shuttle run where WC improved performance found between the wheelchair running (active arm) recovery and passive rest recovery in our study. Though it was well documented that the removal of lactate was faster following exercises at a reduced intensity,(7,39) the mode of exercise incorporated during the recovery phase in most of these studies was similar to that used to produce lactate in the first exercise i.e. leg exercise. In the present study it was focused in examining the effectiveness of contrasting modes of exercise on removal rate of lactate, physical tests and subsequent performance. So wheelchair running was used as a mode of active arm recovery after the high intensity intermittent running exercise on a treadmill until exhaustion. The result seem to indicate that no clear advantage is afforded to the athlete who assumes the wheelchair running following strenuous exercise than the passive rest and in fact it appears to be, absolutely no difference between supine recovery and wheelchair running perhaps both the modalities resulted in enhancing recovery. The result seem to indicate that no clear advantage is afforded to the athlete who assumes the wheelchair running following strenuous exercise than the passive rest and in fact it appears to be, absolutely no difference between supine recovery and wheelchair running.

The present study has its own limitations with the respect to size of the sample and also on only male athletes included. Though we informed previously to subjects that they should be abstained from food 8-9 hours and water for 3 hours prior to the experiment, we couldn't control the nutritional status of the subjects at the time of the experiment. Moreover the psychological factors of the subjects were out of control while experiments as the subjects were selected for the study 3 days prior to the actual experiment.

Conclusions:

It is concluded that both wheelchair running and passive recovery are same in the efficiency of blood lactate removal and restoration of physical performance following intense intermittent exercise with wheelchair running exerting no noteworthy effect on the physical performance tests of stork stand, vertical jump, sprint and shuttle run than passive recovery.

There is a need to conduct some further studies on the related areas such as,

- Wheelchair running recovery should be compared to the other active arm and leg recovery modalities.
- The potential effects of nutrition on active and passive recovery effectiveness should be studied.
- Further studies should focus on the physiological response, blood haemotocrit response and hormonal response to these exercise and recovery modalities.

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