

Effects of intermittent pneumatic compression vs. neuromuscular electrical stimulation on recovery following anaerobic exercise in male basketball players

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Abstract

Objective: To compare the effects of Intermittent Pneumatic Compression (IPC) vs. Neuromuscular Electrical Stimulation (NMES) on recovery following anaerobic exercise.

Design: Three-arm comparative pretest-posttest experimental design

Setting: University Sports complex and Physiotherapy Clinic.

Participants: Twenty-four male collegiate basketball players aged 18-25 yrs (mean± SD 20.4±1.8 yrs)

Interventions: Participants were randomly assigned into one of the 3 groups; IPC group (n=8), NMES group (n=8) or control group (n=8). Each group performed a repeated sprint test (RAST) following which, the subjects received IPC, NMES or no intervention as a recovery mode, for 20 minutes.

Main outcome measures: Blood lactate recorded prior to and at 5, 15 and 25 min following the RAST. Following recovery, subjects performed another bout of RAST to assess for peak power, mean power, and fatigue index, as parameters of anaerobic performance.

Results: There was a significant difference in the clearance of blood lactate between three groups ($p=0.006^*$), with NMES group showing greatest drop. The performance decrements in the second bout of RAST were significantly less for the NMES group as compared to control ($p<0.05$).

Conclusion: NMES was more effective than IPC or passive rest, in clearing blood lactate and minimizing performance decrements following an anaerobic exercise bout.

Keywords: Blood Lactate, Anaerobic Power, Fatigue index.

1. Introduction

Basketball has gained worldwide popularity, and fascinated players and spectators with its dynamic characteristics as a team sport [1]. During a basketball game, players cover about 4500-5000m with various directional, multidirectional, intense and short lasting movements [2]. The results of time-motion analyses reveal that these multi-sprints with forward, backward and lateral displacements, contribute approximately 40% to the total game activities [3]. Elite basketball players spend 75% of playing time with a heart rate greater than 85% of its maximum value [4]. Indeed, a large amount of jumps and sprints occur during a game, demonstrating the importance of anaerobic power [4-

7], and the fairly high average blood lactate values recorded in competition show a significant involvement of the glycolytic energy system, also referred to as anaerobic capacity [4, 8]. Therefore, it seems logical that testing procedures that incorporate anaerobic power and sport specific movements would provide a valuable tool to assess and monitor components of basketball performance [9]. Nevertheless, it has been reported that the repeated-sprint tests, instead of a single sprint, are more appropriate and mimic the movement pattern of most games to ensure physiological demands of the competition [10, 11] & a valid procedure to assess anaerobic power in basketball players [12]. Studies demonstrate relatively high physiological

demands of competitive basketball, as evidenced by the elevated lactic acid and sustained high heart rate response [4, 8]. This acute accumulation of blood lactate due to high physiological demands can induce metabolic acidosis which sequentially can decrease the work capacity of muscles, leading to a decrease in performance [13].

Hence, fast recovery after fatiguing exercise is an important factor for better performance [14]. Recovery mode is of importance in the determinism of intermittent high-intensity exercise like basketball. This is because most of the high-intensity exercise bouts during basketball are performed from an active state and only rarely do players stand still before an explosive bout of activity [4]. A wide range of modalities are now used as integral parts of the training programmes of athletes to help attain balance between competition stress and training, and to aid faster recovery. Modalities used for recovery include massage, active recovery, cryotherapy, contrast temperature water immersion therapy, hyperbaric oxygen therapy, nonsteroidal anti-inflammatory drugs, stretching, compression therapy, electromyostimulation and combination modalities [15]. As compared to passive rest, applying recovery modalities might enhance recovery [16] by various mechanisms such as, increased blood flow causing metabolic by-product removal [17] and increased vessel permeability that would reduce muscle damage markers efflux [18]. Moreover, compression and electrical stimulation are the most widely used interventions for rehabilitation and recovery purposes. IPC comprises of pumped inflation and deflation of air bladders within cuffs that cover the foot, calf or whole leg, and mimic the anatomical muscle-venous pump to circulate blood [19]. The inflation can be applied uniformly and sequentially with a variety of pressures at rapid or moderate rates. Zelikovski *et al.*, [20] demonstrated improved exercise time and a 45% improvement in exercise performance, with dynamic IPC treatment between bouts of exhaustive exercise. Electromyography (EMG) studies show that muscles fire more effectively when treated with IPC [21].

The use of neuromuscular electrical stimulation, on the other hand, has gained popularity in amateur as well as professional sports for enhancing both strength and recovery [22]. NMES involves a series of stimuli, delivered superficially using electrodes placed on the skin. It has been suggested that sub-tetanic NMES could be effective for enhancing sports recovery owing to its analgesic effects on muscle soreness [23], and its role on post exercise muscle metabolite removal, secondary to increased blood flow and lymphatic drainage to the stimulated area [24]. Low frequency electrical stimulation is the commonly used mode for the recovery process because it induces light muscle contraction responsible for muscle pump effect & therefore enhanced muscle blood flow. NMES also favors the resynthesis of phosphocreatine [25]. In addition, a decrease in heart rate suggests that efficient blood flow stimulation by

NMES can alleviate the stress placed on the heart [26]. To the best of our knowledge, no previous study has compared these two widely used modalities. Therefore, the purpose of this study was to examine the effects of Intermittent Pneumatic Compression vs. Neuromuscular electrical stimulation on recovery following an anaerobic exercise bout in male collegiate Basketball Players.

2. Materials and Methods

2.1 Subjects

24 male collegiate basketball athletes (Mean \pm SD for age 20.4 \pm 1.8 years, height 1.73 \pm 0.06 m, weight 65.37 \pm 5.56 kg and BMI 21.67 \pm 2.08) from Jamia Millia Islamia, New Delhi, India participated in the study. Ethical approval was granted by Institutional Human Ethical Committee and the subjects were given written informed consent. Inclusion criteria required by participants to be males aged 18 – 25 y/o, healthy and physically trained with playing experience between 1-5 years and were involved in basketball training and competition on a regular basis & the subjects having any history of recent injury (< 6 months) or any acute/ chronic cardiovascular or metabolic complications & Use of recreational or performance enhancing drugs were excluded from the study. Participants were instructed to eat as normal and to stay well hydrated & refrain from any form of exercise, Caffeine and alcohol consumption 24 hrs prior to session. The sample size was estimated using data of changes in blood lactate from the study done by Seo *et al.* [27], in which effect of electrical stimulation on blood lactate after anaerobic muscle fatigue was analysed and 6 subjects per group were shown to be necessary based on the effect size of 3.1, alpha level of 0.05 and power (1-beta) of 0.95. Eight subjects each group were used to increase the power of the study. There were no dropouts in the study as it was one time study.

2.2 Experimental Design

Subjects were tested on one day only. Prior to each test, the subjects were given a demonstration of the tests. Stature (m) and Body mass (kg) were recorded using a wall mounted stadiometer to the nearest 0.1mm & 0.1kg. After inducing fatigue with six successive sprints with 10 sec interval in between, subjects were assigned to 20 min recovery intervention period, consisting of either an IPC, passive or NMES recovery intervention. The criterion measures used in the study were Blood Lactate, Peak Power, Mean Power & Fatigue Index.

2.2.1 Repeated Anaerobic Sprint Test Protocol [28]

The RAST was used to determine the fatigue index (FI) and power: maximum (Pmax), average (Pavr) and minimum (Pmin). This test required Grass field, Two Cones, Two Stopwatches, Two Assistants & the athlete to undertake six 35 meter sprints at maximum pace with 10 seconds recovery between each sprint after warm up for 10 minutes. Time was recorded with the help of stopwatch.

2.2.2 Neuromuscular Electrical Stimulation Group

The NMES group underwent electrical muscle stimulation for 20 min period using IFT (Endomed 684) applied at 10 ± 20 Hz to the medio-central part of the calf of both legs via suction electrodes. The carrier frequency was set at 4 kHz. The pulse duration was fixed at 125 µs to induce sufficient muscle activation [29]. The current intensity was set within the range of the minimum visible contraction of the calf muscles.

2.2.3 Intermittent Pneumatic Compression Group

The IPC device used in this study was Air compression system (MK 400, DS MAREF) and consisted of two leg sleeves that were worn on both legs and it covered foot, shank and thighs then the leg sleeves were connected to the automated pneumatic pump at which target inflation pressure and duty cycle can be controlled. Pressure was set at 80 mmHg and B mode (Squeezing mode) was selected. There was 2 compression cycles per minute. Speed was set at 6 [21, 30].

2.2.4 Control Group

In control group subjects received no treatment for duration of 20 minutes. During recovery period, talking and excessive movements was avoided & were instructed to remain in supine lying position for 20 minutes. BLa was recorded prior to and 5min immediately following of the 35m RAST test & at an interval of 10 mins during recovery periods. After the completion of recovery, subjects performed another bout of RAST to assess for performance. PkP, MP, and the FI were measured as parameters of anaerobic performance and were determined by the following equations [31].

$$\text{Power} = (\text{Body mass} \times \text{Distance}^2) / \text{Time}^3$$

Pmax= maximum power value among the six sprints

Pavr= Σ of 6 power values/6; Pmin= minimum power value among the six sprints

Fatigue Index (%) = [(maximum power – minimum power)/maximum power] x 100.

2.3 Data analysis

Data were assessed by Shapiro-Wilk test to check for the normality of the distribution scores. The demographic characteristics and the baseline criterion measures were compared between the groups using one way ANOVA. 8 participants in each group were tested at 4 time points for blood lactate values, a 3x4 split plot ANOVA with group (control, experimental), time (pre,5min,15 min,25 min) and interaction effect (Group × Time) was employed to assess for changes in blood lactate. When the main effect of group was significant, a Bonferroni test was employed as post hoc analysis to locate groups showing significant difference. To test for performance changes across the 3 groups, ANCOVA was used with the pretest values as covariates. Significance level was set at p<0.05.

3. Results

Subjects’ demographics and baseline characteristics showed no difference between the three groups (Table 1). Comparison of post intervention scores showed a significant difference across the three groups (p <0.05). Table 2 shows the results of post hoc analysis conducted to locate the points of significant difference. The IPC group although demonstrated a superior recovery in comparison to the control group (lower blood lactate and decrements in performance), only the NMES group yielded a significant difference from the control, for all test variables (Figures 1-4)

Table 1: Subject Characteristics

Variables	Group 1 (Mean±SD)	Group 2 (Mean±SD)	Group 3 (Mean±SD)	F-values	p-values
Age(years)	20.12±1.80	20.62±1.40	20.57±2.30	0.17	0.84
Ht(m)	1.71±0.06	1.72±0.04	1.76±0.09	0.92	0.41
Wt(kg)	64.12±8.14	64.17±6.16	67.83±2.38	0.98	0.38
BMI(kg/m ²)	21.37±2.08	21.68±2.25	21.96±1.91	0.15	0.85

BMI: body mass index; Wt: weight; Ht: height; data are presented as Mean (SD); significant difference = p<0.05.

Table 2: Baseline Characteristics

Dependent variable	Group 1 (Mean±SD)	Group 2 (Mean±SD)	Group 3 (Mean±SD)	F-values	p-values
Bla	2.55±0.93	2.67±0.56	2.45±0.64	0.19	0.82
PkP	867.69±72.87	807.72±107.02	744.14±103.58	3.33	0.05
MP	575.74±61.03	499.22±65.39	538.02±62.49	2.95	0.74
FI	54.61±9.30	53.88±10.68	49.66±6.96	0.68	0.51

BLa: Blood Lactate; PkP: Peak power; MP: Mean Power; FI: Fatigue Index are presented as Mean ± SD; significant difference= p<0.05

Table 3: Post Hoc Analysis for groups

Groups	BLa Mean(SE)	PkP Mean(SE)	MP Mean(SE)	FAI Mean(SE)
NMES	7.23±0.74	723.92 ± 33.89	553.20 ± 25.64	45.49 ± 3.49
IPC	8.38±0.74	698.97 ± 34.09	499.34 ± 25.79	54.72 ± 3.51
Control	10.97 ±0.74	528.40 ± 34.98	423.10 ± 26.46	64.84 ± 3.60
<i>Post hoc analyses p-values</i>				
NMES vs. control	0.006 *	0.004 *	0.011 *	0.005 *
IPC vs. control	0.070	0.012 *	0.201	0.221
NMES vs. IPC	0.874	1.00	0.501	0.261

*significant difference

Figure 1: Mean \pm SD of blood lactate for the groups at baseline and 5, 15 and 25 mins post exercise.

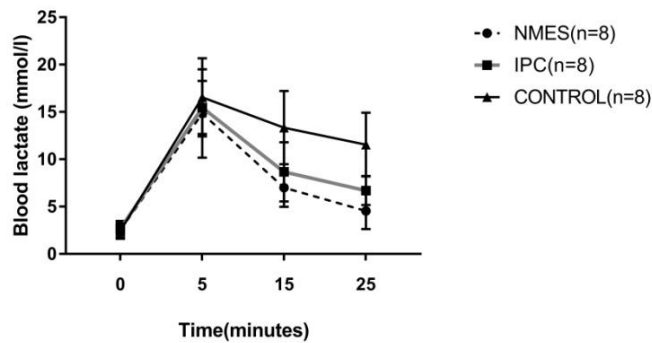


Figure 2: Comparison of Peak power between and within the groups.

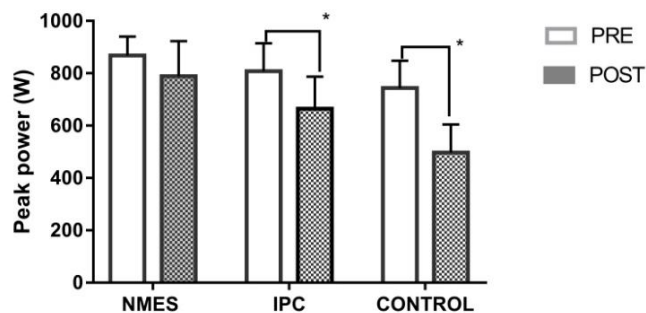


Figure 3: Comparison of Mean power between and within the groups.

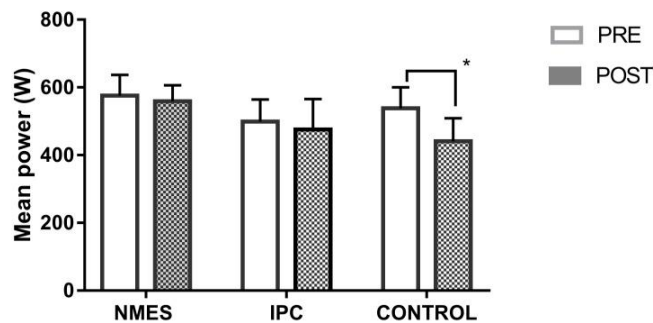
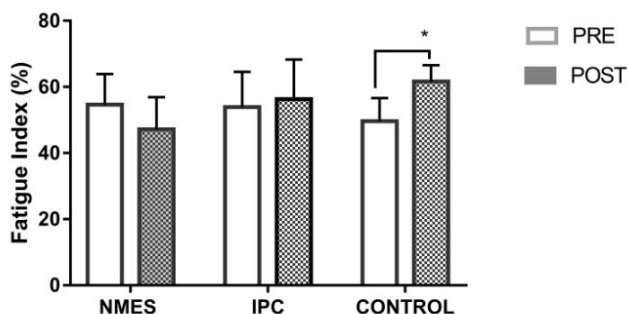


Figure 4: Comparison of Fatigue Index between and within the groups



4. Discussion

The main findings of the present study suggest that NMES showed significantly better recovery as compared to the control or IPC groups, both in terms of its effects on blood lactate clearance and running performance recovery of RAST test. Many studies have reported that active recovery lowers lactate faster than passive recovery [32] but former may not always be practical. So, this study aims to find out

the best recovery method which is practically feasible. The physical performance parameters used during the study were Peak Power, Mean Power and Fatigue Index. The fatigue protocol employed herein was repeated anaerobic sprint test which is very well validated in basketball players [12, 33-37]. The RAST output (i.e., Blood lactate, peak power, mean power, fatigue index, maximal speed, and mean speed) are similar to those determined in WAnT, showing high correlations with the same variables [12].

The NMES groups in the present study was administered a low frequency electrical stimulation during the recovery period showed a significant recovery of blood lactate and anaerobic performance as compared to control group, which is similar to the results found in previous studies [21,24,26,27,30,38-41], although some studies have also reported contrasting findings [21,42-44]. IFT used produces biphasic pulses within the tissues & has an advantage in that it does not cause skin irritation unlike some other electrical techniques [45]. NMES which uses medium frequency alternating current induces vasodilation & increase peripheral blood flow [46,47] & the suction system with an electrode has a massage effect [27]. Also the rest position during NMES favors the resynthesis of PCr [25]. The calf muscles stimulated in this study are largely responsible for venous return [48] and may have aided a better recovery. The reasons for the IPC's success in decreasing BLa more than the passive recovery in this study might be due to its ability to mimic the muscle venous pump [39,49]. IPC has a potential role in altered limb circulation, lymphatic flow & general metabolic clearance [30,40,50-53]. The results suggest that IPC may be superior option to passive recovery when "inactive" BLa clearance is desirable (eg. Energy sparing). The result of our study yielded a significant difference between IPC and Passive recovery on performance & also it has been previously shown in a study done by Zelikovski [20] that applying IPC on the lower limbs of volunteers immediately after they had experienced muscular fatigue yielding a 45% improvement in muscular performance by significant improvement in the venous return which leads to muscle cells shifting to an aerobic metabolism [21]. Donnell *et al.*, [54] also found recently that IPC application in comparison to passive recovery during a 30 minute recovery period following a 40-minute high-intensity interval exercise bout on a cycle ergometer, in well trained male triathletes, accelerated the removal of metabolites from the muscles through milking effect and therefore improved the performance in a subsequent exercise bout in comparison to passive recovery.

The results of this study yield a non significant difference between the effect of NMES and IPC on blood lactate clearance & anaerobic power recovery after the anaerobic exercise. When we compared the no treatment group, NMES was found to be better than IPC in enhancing recovery and performance, this may happen due its analgesic effects on muscle soreness [23], neuro-mediator release like

endorphin that may induce transient analgesia [55] and its role on post exercise muscle metabolite removal, secondary to increased blood flow and lymphatic drainage to the stimulated area [24]. These NMES group findings are supporting the previous finding of one recent study on comparison of NMES vs. IPC on lower limb hemodynamics in DVT patients [56]. So, we can conclude from the result NMES is better mode of recovery as compared to IPC and passive rest.

5. Practical considerations

NMES is silent, portable, cost effective and a viable alternative to IPC in the field setting due to its easiness of application, accessibility & very favorable usability characteristics which would support a high rate of compliance. NMES & IPC are better than passive recovery, so they are preferred method of choice for recovery than passive rest & advantageous, especially where “inactive” BLa clearance is desirable (eg. Energy sparing) or other popular mode of recovery like active recovery cannot be performed such as during half time interval; training or multiple competitions in a day.

6. Conclusion

The results of the present study demonstrate a significant difference between the three groups, in the recovery following an anaerobic exercise bout, both in terms of blood lactate clearance and the performance decrements in subsequent exercise bout. NMES showed a significantly better recovery profile as compared to the control group. IPC group although better than the control group, did not prove to be as effective as the NMES intervention. So, we can conclude from that NMES is a better alternative to IPC or no intervention for the enhancement of recovery following anaerobic activity.

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