The Role of AEROBIC and Anaerobic Training Programs on CD ^{341} Stem Cells and Chosen Physiological Variables

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Abstract

The purpose of this study was to reveal the role of aerobic and anaerobic training programs on CD^{34+} Stem Cells and Some Physiological Parameters. Twenty healthy male athletes aged (18-24 yrs.) were recruited for this study. Healthy low active males and BMI matched participants (n=10) aged (20-22 yrs.) were recruited as controls. Aerobic and anaerobic training programs for 12 weeks were used. $VO2_{MAX}$ pulse estimation using Astrand Rhyming protocol. RBCs,WBCs,HB and hematocrit were estimated using coulter counter, Lactate by accusport, CD^{34+} stem cells by flow cytometer. Results: $VO2_{MAX}$ was increased significantly in case of aerobic training program compared to anaerobic one (62±2.2 ml/kg/min)

(54±2.1 ml/kg/min). Haemotological values increased significantly in anaerobic program compared to aerobic, RBCs (5.3±0.3 and 4.9±0.2 Mil./ul), WBCs (6.6±0.5 and 6.1±0.4 Thous/ul), HB(15.4±0.4 and 14.2±0.5 g/de) Hematocrit (4.6±1.2 and 4.4±1.1 %), CD^{34+} stem cells count increased significantly in case of anaerobic program than aerobic (251.6±21.64 and 130±14.61) and sedentary (172±24.10). These findings suggest that anaerobic training program provoke better adaptation to exercise and stem cell counts may differ between trained and sedentary Circulating immature cells are likely to be involved in angiogenesis and repair process, both mechanisms being associated with strenuous exercise, knowledge of the physiological of effects of training on stem cells might be of potential clinical use.

Key words: *Aerobic and anaerobic training programs, CD^{34+} stem cells, physiological parameters.*

Introduction

Exercise is one of the most powerful non-pharmacological strategies, which is able to affect nearly all cells and organs in the body. In this context, a new research avenue focusing on the action of exercise on adult stem cells has emerged during the last decade. Changes in the behavior of adult stem cells from different regions, including skeletal muscle and the cardiovascular system have been shown to occur in response to exercise. In general, exercise, both acute and systematic training, has been found to stimulate increases in circulating EPCS in healthy subjects and patients with cardiovascular disease, although there are few studies that lend insight into the mechanisms and signaling that connect exercise with stem cell release and action (Witkowski, 2008)

Through its action on adult stem cells, exercise may act on the regenerative potential of tissues by altering the ability to generate new stem cells and differentiated cells that are able to carry out tissue specific functions (Kado andThornell 2000). Strength and power are important aspects of fitness, sport and everyday activity. However, much debate remains as to how these qualities, should be evaluated. Much of the debate originates from the definition of strength and power as well as the different terminology used across laboratories. Sale (1991) defined strength as the force exerted under a given set of conditions during a maximal voluntary contraction (MVC). Sale continued to define power as the rate at which mechanical work is performed under a specified set of conditions, or the product of force and velocity. Both definitions imply that strength and power are defined by conditions such as velocity, contraction type, posture and movement pattern specificity.That is strength *for one task may not imply for another one. Strength and power are quite often measured in contexts dissimilar to the environment in which functional strength and power are needed (Fatourous et al., 2000).*

Guyton and Hall (2006) reported the effect of athletic training on muscles. They stated that muscles that function under no load, even if they are exercised for hours, increase little in strength. On the other hand, muscles that contract at more than 50% maximal force will develop strength rapidly even if the contractions are performed only a few times each day. They also added that during muscle contraction blood flow increase about 13 fold but also the flow decreases during each muscle contraction. This decrease in flow is due to the compression of intramuscular blood vessels, but the blood flow to muscles increases during contraction.

In a recent study, Burd et al. (2010) investigated the impact of two distinctly different exercise volumes on anabolic signaling myogenic gene expression, and rates of muscle protein synthesis (Mix, Myo, Sarg), specifically, they utilized a unilateral model in which subjects performed exercise at 90% 1RM until failure (90 FAIL), 30% 1RM in which the amount of external work was matched to 90 FAIL (30 WM), or 30% 1RM to failure (30 FAIL). They reached the conclusion that low-load high volume resistance exercise is more effective in inducing acute muscle anabolism than high load low volume or work matched resistance exercise modes.

As for training induced adaptations, exercise induced neutrophilia was shown to become progressively blunted with training (Suzuki et al., 1999), but no other study tested whether circulating HPC counts may differ between trained and sedentary subjects. Circulating immature cells are likely involved in angiogenesis (Reyes et al., 2002) and repair processes (Springer et al., 2001), both mechanisms being possibly associated with strenuous exercise and progressive training. Given the large use of exercise based rehabilitation programs in several diseases, knowledge of the physiological effects of training on HPCs might be of potential clinical use.

Identification of EPCs on the cell surface expressions of various protein markers. There is no straight forward definition of an EPC marker because these cells seem to be a heterogeneous group associated with different cell surface antigen expression profiles. The most commonly described molecules that serve as biomarkers for recognition of an EPC population include CD34+, CD133, and VEGFR2. The pioneer study of Asahara et al (1999) recognized EPCs as CD34+ mononuclear cells (MNCs). Hematopoeietic stem cells that serve as a source of EPCs express CD34+, however this marker is also present on the surface of mature endothelial cells (Fina et al., 1990).

Patrick and Stephane (2003) found CD^{34+} stem cell from elite triathletes to be significantly lower than in healthy sedentary subjects. They stated that the low CD^{34+} counts and neutopenia and low lymphocyte counts could contribute to the increased upper respiratory tract infections observed in these athletes. They hypothesized three explanations (1) Aerobic training could induce deleterious effect on BM by inhibition of central CD^{34+} SC growth (2) intense training could depress the mobilization of CD^{34+} SC. (3) due to aerology of the damage / repair process. They conclude that CD^{34+} SC quantification in elite athletes should be helpful for both basic science research and sport clinicians.

The aim of this study was to reveal the role of aerobic and anaerobic training programs on CD34+ stem cells and some physiological variables.

Material and Methods

Participants:

Twenty healthy male athletes aged 18-24 years with a training history of 4-9 years were recruited for this study. Athletes had to engage in regular exercise at least 3 days/week. Healthy low active male and BMI matched participants (n=10) aged -20-22 yrs. - were recruited as controls. Control subjects could not have a recent history of regular exercise. Participants were screened and asked to fill out a health and physical activity history questionnaires.

All participants were nonsmokers, non-diabetic and free of cardiovascular, lung and liver diseases. Participants did not take any medications that affect EPCs number or function. These include statins, angiotensin I I receptor antagonists, ACE inhibitors; peroxisome proliferators activated receptor ($PPAR\alpha$) agonists and EPO.

Statistical Analysis

Student's t tests were used to determine the differences between athletes and control groups and between aerobic and anaerobic groups when exercise protocols data were found to not meet the assumption of normality, the non-parametric Mann Whitney U test (Wilcoxon rank sum test) was used to compare difference between groups. In these cases, for descriptive data the median (Lowest value-highest value) is displayed. Differences between groups were tested using the analysis of variance (ANOVA). For parameters with non-normal distributions non parametric Spearman correlation coefficients were used. F test was used to test 3 groups .An α level of 0.05 was used to indicate statistical significance.

Aerobic Training Program After Dr. Phil Esten (2010)

Early season phase: this training phase takes place during the first 4 *weeks of an 12 week program.A typical week in to follow aerobic-paced mileage (3miles) on Monday to Wednesday with a hard up-tempo workout on Tuesday (anaerobic threshold and race pace), a softer up-tempo workout on Thursday, 20-40 minutes of easy running on Friday, a race on Saturday and Sunday off., weight training on Monday and Wednesday During the early season phase the athletes should have one very long run every 14 days and the workouts should progress in duration every 2 weeks by 5 minutes. Intensity = HR of 140-150beats/m. Midseason phase should begin after 4 weeks and continue through week 8. During this phase, the runners should have one very long, aerobic paced run every 14 days (20-50%) longer than their run of the week. Progression every 2 weeks increase running time by 5 minutes, weight training continue on Monday and Wednesday. A big difference with this phase as compared with the early phase is that both duration and intensity of the work bouts should be at a higher level.*

Final phase covers the last 4 weeks of a 12 week training program. It is important to continue with sufficient aerobic pace runs to ensure stride efficiency. By maintaining duration (minutes the 5 percent cut back per week), increasing the rest interval, and slightly decreasing the intensity of the repetitions, the runner recovers from the midseason work and performs at optimal levels.

Anaerobic Training Program After Tom Green (2003)

Training three times a day: on Monday, Tuesday, Thursday and Friday. Saturday is reserved for a single specific workout and high intensity.

-1sr workout 20-45 minutes active warm-up, max velocity sprint, plyometric/bounding and a cool down of 10-15 minutes.

-2nd workout 20 minutes warm-up, main workout and general conditioning, 10-15 minutes cool down.

3rd workout weights using high load (70%IRM)

-Saturday workout is typically late morning or early afternoon.

As the season progresses the workout program gets increasingly more technical, specific and fine-tuned, intensity increased reaching 170 beats/min. After properly warmed up for 20 minutes, the first workout spends 30 minutes to an hour of work on maximum velocity sprint and /or plyometric.

The second workout throughout the week:

Monday: 30 second sprint, then 10 minutes rest, then sprinting at 80% up a hill, around 100 meters, cool down. Tuesday: warm up, standing in place – running arm swings, perform with dumbbells (5-25 Lbs) then single leg squat, with 2 minutes rest between each set. Wednesday –rest and recovery.

Thursday: warm up, the workout in place weighted arm swings 10 sets of 60 seconds on with 60 second off, and then cool down.

Friday like the workout of Monday then cool down

Saturday: workout is used for active recovery

The third workout of the day weight training progression –increase weight, sets and reps increase to allow the body to peak. As the athlete adapts to training the rate of progression can be increased

Results

Subjects characteristics:

Twenty athletes and ten low active control males participated in the study. Groups were matched for age, body mass and body height (table 1). Also for BMI, non-significant changes in basic characteristics, to compare athletes and control males.

Heart rate and VO2 $_{MAX}$ showed significant changes (Table 1), as expected athletes had a lower heart rate compared to control. Physical activity questionnaire data revealed that athletes exercised an average of 5±0.5 days a week for 5±0.2 years.

The control group was not engaged in regular exercise, nor did they have a recent history of physical activity.

Twenty athletes agreed to participate in a 12 weeks of training sessions of aerobic and anaerobic exercises.

Discussion

Tables 1 and 2 revealed lower values of lactate after aerobic and anaerobic training programs which mean a better fitness. Lactate is the end product of the anaerobic carbohydrate breakdown. It is the metabolite displaying the most spectacular concentration changes in muscle and blood with exercise. As a result, its measurement offers a wealth of information regarding the effect of exercise on metabolism. Lactate is usually determined in blood plasma (Mougios, 2006). Peak lactate concentration after short maximal exercise is reached after 3-5 minutes. Thus, a blood samples taken immediately after the end of exercise will not produce peak values.

Programming training based on blood lactate concentration is superior to programming based on heart rate because lactate relates directly to muscle metabolism and muscle adaptations. Thus, one could use lactate to determine training intensities at the beginning of a training program, monitor training through heart rate on a daily basis, and relate to lactate every few weeks to control the intensity. Most scientists agree that exercise intensities below 4mmol/L are most effective in improving aerobic endurance, cardiac function and the lipidemic profile (Mougios, 2006); Greenhaff and Timmons, 1998).

Barrett et al. (2010) stated that blood consists of a protein rich fluid known as plasma, in which cellular elements are suspended: white blood cells, red blood cells and platelets. The normal total circulating blood volume is about 8% of the body mass (5600 ml in a 70 kg man). About 55% of this volume is plasma. Red blood cells, white blood cells and platelets are formed in the bone marrow, which is actually one of the largest organs in the body, approaching the size and weight of the liver. Hematopoietic stem cells (HSCS) are bone marrow cells that are capable of producing all types of blood cells. They differentiate into committed stem cells (Progenitors cells). The Hscs are derived from uncommitted, tot potent stem cells that can be stimulated to form any cell in the body. Adults have a few of these, but they are more readily obtained from the blastocysts of the embrio.

Robergs and Roberts (1997) stated that the main functions of the cellular components of blood are the transport of oxygen and carbon dioxide, blood clotting, acid base buffering immune functions and tissue repair and destruction, and the function of plasma (liquid components) are blood clotting, circulating or cellular components and their contents, heat transfer and thermoregulation, water exchange and transport, circulation of hormones, acid base buffering, circulation of metabolites, nutrients and waste products.

Burge et al. (1993) and Gillen et al. (1991) reported that acute effect of exercise on blood is to cause a release of fluid from the vascular component, which decreases the volume of plasma and blood. This fluid loss from plasma decreases plasma volume and causes hematocrit and plasma metabolite concentration to increase, which is termed hemoconcentration. In fact, a significant hemoconcentration occurs when a person moves from a supine to a vertical position. The added hemoconcentration of exercise is predominantly confined to the transition from rest to exercise. This response is followed by a more gradual hemoconcentration that occurs with increases in exercise intensity. And these changes are greater during higher blood pressure associated with resistance exercise than during more prolonged dynamic exercise.

Spriet et al. (1986) added that prolonged exercise involving sweating increased fluid loss from the body, and the degree of hemoconcentration can be evaluated by either directly measuring plasma volume or estimating relative changes in plasma volume from hemoglobin and hematocrit measurements. Also blood viscosity increases above what would be expected for hemoconcentration effects. In addition, there is destruction of erythrocyte, termed hemolysis, which increases plasma hemoglobin concentration (Zierler et al., 1992). This was in accordance with the *increased cellular changes after training programs due to hemoconcentration Table 3.*

Endurance training increases the volume of blood. The ventricle can hold and contributes to its maximum stroke, ventricular thickness is usually slightly increases. The blood cells, Rbs, Wbcs, platelets and Hematocrit as well as hemoglobin are slightly increased together with stem cells SC, CD^{34+} (Tables 2, 3).

As for the adaptive response to anaerobic exercise, blood cellular components of Rbcs, Wbcs, Hct and haemogbin numbers and contents increased together with increase CD^{34+} SC compared to aerobic one and control CD^{34+} (25,6±21,64) (130±14,61) and 170±21.10 (Tables 2.3), this was in accordance with the results of Bonsignore et al. (2002) (2010) and, Mobius – Winkler et al., 2009.

Robergs and Roberts (1997) stated that the most important chronic adaptation increasing long term muscular endurance is an increase in number and size of mitochondria. An increased mitochondrial volume would also provide skeletal muscle with the ability to increase $VO_{2\ MAX}$, However, cardiovascular adaptations are also involved in increasing $VO_{2\ MAX}$ after training. Table(4) indicated an increased $VO_{2\ MAX}$ after aerobic training program compared to control and anaerobic one.

Amani and Mohamed (2011) reported the effect of endurance and resistance training on CD^{34+} / CD^{45+} Stem cells, $VO_{2\ MAX}$, certain physical variables and time of 1500 m.Run. They came to the results that there was a significant increase between pre and post measures in accounting of CD^{34+} / CD^{45+} Stem cells, VO_{2MAX} and time of 1500 m. run for the sake of endurance and Resistance training. They concluded that the training procedure for two months can improve physical and time together with increased stem cells among young runners.

Resistance exercise stimulates the synthesis of skeletal muscle proteins (West et al., 2009), which is expressed as muscle hypertrophy. It has recently been established that, myofibrillar (My) protein synthesis is already maximally stimulated at 60% 1RM, in the post absorptive state, with no further increase at higher load intensities (75 – 90 % 1RM) (Kumar et al., 2008).

Additionally, performance of low load contraction (20 1MR) with vascular occlusion is sufficient to induce an increase in mixed muscle (Mix) protein synthesis (Fujita et al., 2007).

Burd et al. (2010) reported that low-load high volume resistance exercise is more effective in inducing acute muscle anabolism than high-load low volume or work matched resistance exercise modes. Fifteen young men (21±

1 years), performed 4 sets of unilateral leg extension exercise at different loads and/or volumes. 90% of (1RM) until volitional failure (90 Fail) 30% 1RM work matched to 90% fail (30 wM), or 30% IRM performed until volitional failure (30 FAIL).

Regular physical activity is associated with enhanced endothelial function which has been related to lower incidence of cardiovascular disease (Delp et al., 1993; Delp 1995; Hambrecht et al., 2003 Haram et al., 2006).

Bonsignore et al., (2002) suggested that increased HPCS reflect on adaptation to recurrent, exercise-associated release of neutrophils, stress and inflammatory mediators, indicating modulation of bone marrow activity to habitual running. Laufs et al. (2004), measured EPCS in mice and patients with stable CAD. Mice engaged in 3 weeks of voluntary wheel running and humans underwent a 4 week training program of bicycle ergometer endurance exercise (60- 80% of VO_{2max}), strength exercise, and walking. EPC number was significantly increased in the blood, bone marrow of mice after 7 days of exercise which persisted for the 28 days of the training program. In human the number increased 78 ± 34% compared to initial level. EPC apoptosis was found to decrease 41 ± 11 % after training. As for Steiner et al.(2005) who utilized a 12 week exercise program in patients with asymptomatic coronary artery disease (CAD). Results showed a 2.9 ± 0.4 fold increase in circulating EPcs in the exercise group. This increase was correlated with an increase in flow mediated dilation and no synthesis.

In another training study, Sandri et al. (2005) analyzed the responses of circulating ($CD^{34\pm}$ / KDR $^{\pm}$) number and function in three patient groups, those with ischemic and training occurred for 4 weeks. Increases in CPC in all three groups were accompanied by an increase in CXCR4, and VEGF. They concluded that the ischemic exercise groups appeared to increase VEGF, which may have stimulated the increase in CPC numbers. Thijssen et al. (2006) reported no change in CD^{34+} / $KD^{\pm}$ cells in healthy young and older participants following 8 weeks of cycle exercise for 20 minutes 3 time per weeks at 65% of heart rate reserve. Therefore, exercise may not increase EPC number in healthy individuals. Hoetzer et al. (2007), Vasankari et al. (1998) reported that exercise may improve the number and function of EPCS while improving oxidative stress status.

Conclusions

It may be concluded that:

Knowledge of the physiological effects of training on stem cells might be of potential clinical use.

Cardiovascular adaptations are involving in increasing VO2 max after training.

Lactate concentration was decreased in case of aerobic training and anaerobic one compared to control meaning a better fitness because lactate relates directly to muscle metabolism and muscle adaptation.

HB, RBCs, WBCs and hematocrit value were increased after anaerobic training compared to aerobic one due to stress.

CD34+ SC counts were increased in peripheral blood of anaerobic training then aerobic one and control due to stress and indicating better adaptation to exercise and modulation of bone marrow activity to anaerobic training.

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The Tables

Table (1)

Basic characteristics

Variable	Athletes N=20			Control N=10			Sig.
Age (yr)	21.6	±	1.83	20.6	±	0.89	NS
Body Height (cm)	179	±	2.78	178.8	±	1.92	NS
Body Mass (kg)	75	±	3.16	74	±	1.5	NS
BMI	22	±	1.4	23	±	2.2	NS
Heart rate (count/m)	68	±	2.3	74	±	2.1	S
VO_{2max}(ml/kg)	52	±	1.8	36	±	1.7	S
Lactate (mmol/L)	1.1	±	0.02	1.2	±	0.03	NS

Values are means ±SE P<0.05
BMI = body mass index

Table (2)

Haematopoietic stem cells for control, aerobic exercise training and anaerobic training courses of exercise for 12 weeks in the resting stages and Lactate

Variable	Control			Aerobic training			Anaerobic training		
CD^{34+}S cells	172.0	±	24.10	130	±	14.61	251.6	±	21,64
Lactate (mmol/L)	1.2	±	0.3	0.8	±	0.1	0.9	±	0.2

Table (2) : revealed a significant changes after anaerobic training compared to aerobic and control in case of CD^{34+} SC (values are means ±SE P< 0.05).

Table (3)

Haematological values of Rbcs, Wbcs, HB and hematocrit (PCV) after aerobic and anaerobic training program (at rest) and control.

Variable	Control			Aerobic training			Anaerobic training			Sig
RBCs (million/ul)	4.7	±	0.9	4.9	±	0.2	5.3	±	0.3	S
WBCs (thousands/ ul)	4.8	±	0.7	6.1	±	0.4	6.6	±	0.5	S
HB (g/dL)	12.8	±	0.8	14.2	±	0.5	15.4	±	0.4	S
Hematocrit (%)	42	±	3.2	44	±	1.1	46	±	1.2	S

Table (3): Revealed a significant change between participant in aerobic program and anaerobic one in hematological value and control ($P<0.05$).

Table (4)

The variation in VO2 max or participants healthy sedentary and after aerobic and anaerobic training programs.

Participants	VO_{2max} (mL/kg/min)		
Healthy sedentary (mL/kg/m)	36	±	1.7
Aerobic training program (mL/kg/m)	62	±	2.2
Anaerobic training program	54	±	2.1

The results are expressed as mean ± SE ($P<0.05$).

Table (4) : VO2 MAX (mL/kg/min) results indicated an increased value between healthy sedentary participants and after aerobic and anaerobic training programs.