RESEARCH ARTICLE ISSN: 2349-2678

Contents lists available at www.ijpba.in
International Journal of Pharmaceutical and Biological Science Archive
PubMed (National Library of Medicine ID: 101738825)
Index Copernicus Value 2017: 71.80
Volume 7 Issue 6; November-December; 2019; Page No. 06-12

THE EFFECT OF 8 WEEKS AEROBIC TRAINING ON SOME IMMUNOHEMATOLOGICAL INDICATORS OF MEN WITH HIGH BLOOD PRESSURE

Ali Alidadi[1] hamed taheri [2] Arman Jalili[3]

[1]Assistant professor of nephrology, Nephrology Department, Zahedan University of Medical Sciences, Zahedan, Iran

[2]Assistant Professor, Department of internal medicine, Zahedan University of Medical Sciences, Zahedan,Iran

[3]Philosophy Doctor (PhD) of Sport physiology. Department of Sport Physiology of Tehran University, Tehran-Iran

Conflicts of Interest: Nil

Corresponding author: Arman Jalili

ABSTRACT

The aim of this researech was to investigate the effects of 8 weeks of aerobic training on some immunohematological indexes of men with high blood pressure. This was a quasi-experimental study in which 20 patients were invited purposefully with high blood pressure at age 40±5 years. The study was performed with 50 to 55% vo_{2max} aerobic exercise. Copel blood samples were collected one day after practice and immunohematological index levels were determined in laboratory. The results showed a significant difference of immunohematological cells levels (leukocytes, lymphocytes, neutrophils, erythrocytes and platelets) before and after 8 weeks of training ($P<0.01$). The results showed that 8 weeks of aerobic training has a significant difference on immunohematological indices of patients with high blood pressure.

Keywords: Aerobic exercise, immunohematological indexes, patients with high blood pressure

INTRODUCTION

In recent years, a variety of physical and physiological changes associated with hematological blood, attracted the attention of many researchers and experts. High blood pressure is one of the most important modifiable risk factors for coronary heart diseases that can be controlled. High blood pressure is a high prevalence in various communities. In many countries the prevalence has been reported between 10 to more than 60%. High blood pressure is involved in heart attack, stroke, congestive heart failure and peripheral vascular diseases. Blood pressure has two components, each time the heart beats, the blood flow in the arteries, and it will open a small amount. The blood pressure is the highest point and is known as systolic blood pressure. In diastole, when the ventricles and arteries are at rest, blood pressure is at the lowest point and blood pressure is called diastolic. If the diastolic pressure equals to or higher than 90 mm Hg and systolic equals or greater than 140 mmHg, person has high blood pressure and adgustment is related by muscular activity, with total blood volume and total plasma volume. In many cases these changes are essential for the development of physical performance. At the same time, changes in the concentration of substances also affects in the blood plasma volume and consequently can have different effects on indicators of immunohematological, metabolites and hormones in the blood and change them. The muscular activity causes changes in the number of blood cells and their metabolic functions. Studies have shown that immune system cells, leukocytes and erythrocytes activities cooperate in the transport of oxygen to tissues (1). On the other hand, some studies have shown that during a strenuous physical activity, several changes have been created in the number of blood cells, their function and protein concentration in plasma (2, 3).

Kalson showed the greatest increase in hematocrit is associated with the release of erythrocytes from the spleen. However, there are minor changes in plasma and extracellular fluid during the activity, especially strenuous activities which changes can have a big impact (4). Regular physical activity may lower blood pressure by an average of 8 to 10 mm Hg. For most patients with high blood pressure, a combination of diet and exercise is the most effective non-drug way in the prevention and treatment of high blood pressure. One of the significant and fixed changes during exercise can be seen in leukocytosis which the increase of

leukocytes to four times may continue during recovery time and after cessation of exercise remain high even after the completion of certain types of exercise for several hours. In general, it seems the amount of leukocytosis to be directly related to the intensity and duration of exercise and is inversely related to an individual's fitness level. The duration of the exercise may be the most important factor. In addition, leukocytosis may be influenced by factors that regulate hormonal responses to exercise. Including of these is the release of corticosteroids, which confirmed the central role of these hormones in the distribution of immune cells following by sport. Increase in the number of white blood cells during and immediately after exercise is often due to an increase in the number of neutrophils and lymphocytes in less level, although the number of monocytes may increase (5). Studies have shown that aerobic exercise caused a significant increase in the number of white blood cells (6). Gleason reported no significant difference in rest leukocyte between periods of intense exercise and low-intensity there in elite swimmers and cyclists (7). Although the number of blood cells may greatly increase after exercise, but long practice (a few hours) may have the effect of instability on the number of circulating cells. For example, Galena (2001) reported that when the 120-kilometer march was performed by male elite athletes for 24 hours the number of leukocytes was lower for 40 hours at rest (8). Some studies have reported of small numbers of lymphocytes at rest in endurance athletes. Green et al. got blood samples from 20 endurance runners when completed practicing their run, respectively. They found that the number of lymphocytes decreased in 10 of the 20 male endurance runners that 5 of them were among the elite athletes and seriously practiced (9).

In this context shepherd did a study where subjects endured the 122 to 123 watts forces for 60 minutes. Concentration of leukocytes and three subsets in peripheral blood circulation leukocytes increased during training. 60 minutes after training, the concentration of granulocytes and leukocytes got to 56 and 66% higher than the initial level, respectively. The concentration of lymphocytes was significantly returned to the primary level 30 minutes after the exercise but demonstrated secondary gradual increase up to 120 minutes after return (10).

According to the presentations and due to the effect of intense exercise on hematological parameters in most sports, athletic performance, especially at higher levels of performance and final result, this study attempts to answer the question that how n anaerobic workout severe impact on the cellular level immunohematological among professional athletes.

Materials and Method:

This study is quasi-experimental. The population of this study was patients with high blood pressure who were referred to the hypertension clinic in Karaj invited purposefully. Of them, 30 patients were selected with a mean age of 40±5 and the average blood pressure over 140. In this study, an aerobic training program lasted 8 weeks in three sessions per week, each session with two hours long and included warm-up at first then the exercise program (jogging 50 to 55% VO_{2max}) and cool down at the end of each session.

Sampling was collected a day before the first practice session and a day after the last meeting by labs and was sent to the laboratory for analysis. This was done using Donor industries. Tools for data collection, included Germany cache medicine balance capable of measuring up to 150 kg and with an accuracy of 1 kg for weighing, 3 meters tape measure in 1 cm width to measure the height, Germany Monarch treadmeal, the American Sysmks electronic cell counter (SYSMEX America, Inc) was used to measure hematological parameters.

In this research, the factors and variables influencing the research domain and in various stages of implementation was controlled such as nutrition, temperature, body mass index, location, age, gender, absence of diseases and conditions, health history, the timing of sleep and activity 48 hours before the test accurately. For this purpose, according to the established schedule, subjects participated in the exercise predicted in this study. Uncontrolled limitations included lack of control over heredity, lack of emotional control and anxiety during the exercise, control over the amount and quality of sleep of the subjects on the day before practice. The results of blood samples were analyzed using the software SPSS version 18. T-test was used to compare the pre-test and post-test of groups at 1% significance level.

Results

Table 1: Anthropometric characteristics such as height, weight, age and BMI

	BMI	Age	Weight	Hieght
Patiants	25±3	40±5	78±5	**177±5**

Table 2: Comparing the mean and standard deviation of leukocytes, erythrocytes, platelets and blood hematocrit of athletes before, after and two hours of practice

Cell	Before practice	After 8 weeks practice	P
Leukocytes	2.13 ± 7.65	2.66 ± 10	0.001
Neutrophil	9.63 83.61	9.04 ± 47.47	0. 006
Lymphocytes	63.9 ± 61.53	6.53 ± 41.75	0.001
Red cells	48.0 ± 48.5	0.50 ± 5.66	0.001
Platelet	45.73 ± 222.71	47.38 ± 243.85	0
HB	1.13 ± 15.08	1.20 ± 15.55	0
HCT	2.99 ± 45.90	3.67 ± 48.52	0

The results showed significantly different at the level of blood cells in athletes before and after 8 weeks of training (0.01>P)

Discussion and Conclusion

The results of this study indicated a significant change in blood cells after 8 weeks of aerobic training in patients with high blood pressure. An increase in blood cells could be due to loss of blood plasma cells, which can lead to lower blood pressure in patients with high blood pressure. In the field of immune response to exercise, despite an increase in infectious diseases, especially in the upper respiratory tract after exercise, there would be no evidence that long-term exercise leads to a detrimental effect and decreased ability of the immune system. It can be referred the well-known adaptations to aerobic exercise training with low to moderate intensity, such as increased production and activity of immune cells. And changes in stimulation of the immune system depends on training conditions, duration and intensity of exercise, sex, race, genetics, nutrition, types of muscle fibers involved, age and other factors (11, 12, 13).Action hematopoiesis is a complex process are influenced by several hormones, cytokines and growth factors. Extreme sports activities and long-term effects on the concentration of several cytokines and hormones that have a stimulatory effect on the proliferation of hematopoietic stem cells to divide and increasing concentrations of tumor necrosis factor alpha, which is (α TNF-), interleukin one beta (βIL-1), interleukin six (IL- 6), granulocyte colony stimulating factor (G-CSF) and release of blood cells (14, 15).

The results Brolinson et al. showed that exercise has different effects on the immune system and sports (team or individual) and exercise play an important role in stimulating the risk factors for infection (16). The aim of this study was to responses to immunohematological cell in the blood of patients with high blood pressure during 8 weeks of aerobic training. According to the results, we can say that aerobic exercise causes changes in white cells, red blood cells, hemoglobin and hematocrit in all patients. In this study, a significant increase has been shown in the number of red blood cells (RBC) and hemoglobin (Hb) and hematocrit (HCT) to be consistent with other research. It seems that moderate aerobic exercises caused different changes in different blood components, including plasma volume increase or decrease in red blood cells, and hematocrit increase or decrease (2, 3). Carlson showed the greatest increase in hematocrit is associated with the release of erythrocytes from the spleen. However, minor changes in plasma and intercellular fluid in the course of activities that can have a significant effect on this change (4). Based on the results of the years 1920 -1930, exercise causes Erytrocytos as blood erythrocyte concentrations may be increased to 25 percent during severe exercise, (18). This change was justified by calling the stored blood, because the blood supply compared with circulating blood cells and plasma little high. During exercise, spleen volumes of dogs decrease to 70 - 87 percent. This means that up to 20 percent more erythrocytes are released into the bloodstream.

However, exercise can increase red blood cells as a result of it has relation with the release of reserve cells (19).

Certain substances have been found in the blood of some athletes, for example and hematocrit and hemoglobin level and white and red blood cells decrease during regular exercise cycles. As a result of the dilution of the blood and increased ability to transfer oxygen and serum globulin levels, triglycerides and cholesterol reduction, this mode of chemicals which are called anti-atherogenic diseases of the cardiovascular ischemia cycle (20). In this study, there is a significant increase in the number of platelets after 8 weeks of training than to practice. In a study the impact of resistance training were tested on blood factors in male non-athletes, the effects of resistance exercise and density of platelet activity in healthy men athlete and it was shown that all physical activity increases blood platelet count and this increase is independent of the intensity of exercise which is consistent with the results of this study and other studies (21, 22, 23). There are significant WBC changes. According to Figure 1 the number of blood leukocytes was significantly increased after exercise. Most researchers noted that exercise-induced leukocytosis probably due to small muscle injury and may develop by inflammation. So that damage by releasing tiny muscle necrosis factor alpha and interleukin one beta activation cause the migration of leukocytes adhesion molecules in the bone marrow, spleen, and other leukocyte resources to the damaged cells. The type of contraction, intensity, duration, workload, level of fitness and health status of the subjects may be involved on leukocytosis levels (24). Some researchers suggest that changes in the physical activity in leukocytes level and the subsets of them can be by a combined effect of epinephrine and cortisol so leukocytosis resulting from short-term activities may be released due epinephrine. Leukocytosis is seen while in the long term activities affected by the stress hormones epinephrine and cortisol hours after the beginning of a long activities (24, 25). In a study total leukocyte increase %79.72 in young subjects after exercise than before exercise and one hour after exercise compared to pre-exercise was 7% higher (24). A study conducted on 18 male rugby league players showed reduction in the immune system of players and decrease muscle glycogen stores or catecholamine production reduction (26). Thus, we can conclude that depending on the type of physical activity, its duration and intensity and other conditions such as ambient (temperature and humidity) and the various sessions of physical activity, changes in the rate of the white blood cells. In one study it was shown that a single session of physical activity increases the concentration and accumulation of white environmental blood cell. But extention and enhance of these changes in the above-mentioned factors on the duration and continuity of activities and external conditions as well as the qualifications and skills depends on the athlete. So we can say that much more active, longer and be more severe, we will have more changes (9). In another study also it was pointed out that increasing the number of white blood cells and subsets directly related to the intensity and duration of exercise, but on the level of physical fitness is inversely proportional (5). Changes in leukocytes and on their ranks during intense exercise and long-term to various factors including timing, intensity and duration of exercise and diet, density hormones and cytokines, depends on changes in body temperature and blood flow and other factors that needs further research and more precise (8).

The lack of consistent of results and findings with Simonson and Macintyre can take root in the level of physical fitness, diversity training programs, intensity, exercise duration, time of blood sampling and measurement methods (27). However, the study on a group of athletes after the test on surface biochemistry values indicated that the rate of lymphocytes and platelets increased in subjects, while levels of neutrophils was so low and is consistent with this research(20). It seems that other factors also have a role on the mechanisms of these changes, so that they can not be attributed only to a specific mechanism. However, the number of changes in the number and distribution of leukocytes and on exercise due to its ranks in most studies, temporary and unstable and it is unclear to what extent these factors affect the immune system. Overall, these findings suggest that changes in immune system cells after aerobic exercise, a significant increase in the number of leukocytes that conform with the findings of a group of scholar (5, 9, 20) and is conflict with Macintyre and Simonson (27). The results are consistent with research of Kargok and Rashida Bhatti and they also concluded that physical stress caused a significant increase in the number of white blood cells (22, 28). It seems profile human immune system response to exercise, requires further studies of longer duration and investigates affecting factors. Another result of this study showed a significant increase in the amount of lymphocytes after sports activities.

Exercise also increases the number of white blood cells after exercise due to compensatory polycythemia may be due to the release of catecholamines and corticosteroids and some hormones, cytokines such as interleukin I. The hormone cortisol modifys in the number and activity of leukocytes into action. (29). Due to the increase in white blood cells in this study, various mechanisms were justified such as the changes in leukocyte surface receptors in lymphocytes (lymphocyte receptor beta-adrenergic). These receptors in the practice of this study operates more quick adjustment and under the influence of epinephrine, increase the number of lymphocytes and the density of adrenergic receptors in leukocytes, because of the leukocytes in the blood circulation (30). Cortisol is a hormone factor that acts as the direction and redistribution of white blood cells, lymphocytes and neutrophils into the tissue. High concentrations of cortisol, the release of neutrophils from the bone marrow, inhibiting the entry of lymphocytes into circulation, return late in the course of recovery so that variations of this hormone as a result of exercise making changes in cellular processes such as protein synthesis or incidence and causes surface receptor expression (31-32-33). Another result of this study indicate that moderate-intensity physical activity in aerobic conditions decreased significantly ((P = 0.001) in the number of neutrophils that the results of the research which is conflict with Ramel et al., Murphy et al., Yamato et al. (30-34-35). Studies suggest that exercise effects on neutrophil function may be due to differences between athletes and the type of workout (36-37). Other studies have also shown that cortisol plays an important role in the increase number of neutrophils after physical activity (38). In addition, cortisol has been shown to influence their target receptor in immune cells called neutrophils from the bone marrow and leads to an increase in the number of neutrophils and leads to leukocytosis (39). Pick and colleagues (2002) reported that cortisol is responsible for the increase of the number of neutrophils after sports activities (40) which is inconsistent of the results of this research. However, some studies have reported the total number of leukocytes and neutrophils increased in the absence of cortisol (41-42). So mediators such as growth hormone, prolactin, catecholamines and muscle damage and other unknown factors comes into play in this regard (42, 43, 44). In another study, neutrophils also increased levels of cortisol was also observed even in the absence of physical activity (41).

Conclusion

According to the results of this study and previous studies, we can say this exercise resulted in a significant increase in the number of lymphocytes before exercise and decrease of neutrophils after exercise. Studies suggest that different exercises effect on neutrophil function and may be due to differences between athletes and workout. On the other hand, it seems that these athletes were not under stress during exercise, cortisol did not increase, thus does not on the number of neutrophils. On the other hand the increase in leukocytes is associated with the release of epinephrine and muscle damage and inflammation and as well as a significant increase in red blood cells due to loss of blood called plasma volume storage and is is associated with a significant increase in hemoglobin and hematocrit due to the release of erythrocytes from the spleen. All exercise increases blood platelet numbers and this increase is independent on the intensity of exercise. It is suggested that in future studies have been done of exercise-induced immune changes proportionally more in relation to the intensity or duration of exercise, frequency of exercise, and possible changes in terms of risk or non-infectious disease, blood and blood pressure compared to a variety of different sports and the number of participants before and after exercise to review the contract carefully.

Refrences:

1. Viru, A,Viru M. Biochemical monitoring of sport training4 ed. Human Kinetics Publishers Inc; Champaign IL 2001.pp1-27.
2. Brun JF, Khaled S, Ranaud E, Bouix D, Micallef JP, Orsetti A. The triphasic effects of exercise on blood rheology: Which relevance tophysiology and pathophysiology.1 ed, ClinicalHemorheology and Microcirculation. 1998; pp. 89-104.
3. Szygula Z. Erythrocyte's system under the influence of physical exercise and training. Sports Medicine. 1990; pp. 181-197.
4. Carlson G P. Thermoregulation and fluid balance in the exercising horse. In: Snow DH, Persson SGB, Rose RJ. Equine Exercise Physiology. Granta Editions: Cambridge;1983: pp. 291-298.
5. Mel nikov AA, Kylosov AA, Vikulov AD.(2007). Relationships of Inflammatory Activity with Biochemical Parameters of the Blood and Sympathovagal Balance of Young Athletes. Human Physiology ,vol.33, No.5. PP624-631.

6. Rashida BhattiB, Din Muhammad SH. The effect of exercise on blood parameters. Pak. J. Physiol. 2007; 3(2):
7. Gleeson, M.; D.C. Nieman;B.K. Pedersen. (2004)."Exercise, nutrition and immune function". J Sports Sci:115- 125.
8. Galun,E.,R.Burstein,E.Assia,I.Tur-kaspa,J.Rosenblum,and Y.Epstein.(2001).chang of white blood cell count during prolonged exercise. International journal of sports medicine 8:253-255.
9. Green,K.J; D.G.Rowbottom;L.T.Makinnon(2003).''Acute exercise and T-Lymphocyt expression of the early activation marker CD69 ''. Med Sci Sport Exerc.35(4):582-588.
10. Shephard. (1999). "Exercise immunity & susceptibility to infection". The Physician & Sport. Med.127(6).
11. Kraemer WJ.Physiological responses to heavey resistance exercise with short rest periods. Int.J.Sports Med. 1987;8:pp:247-152. .
12. SmithL L. Differential white cell count after two bouts of down hill running. Int.J. Sports Med. 1998;19:pp: 432-437.
13. Filadelfi AM, Castrucci, AM. Comparative aspects of the Pineal: melatonin System of Poikilothermic Vertebrates. J. Pineal Res. 1996; 20 (4): PP: 175
14. Smith LL, Anwar A, Fragen M, Rananto C, Johnson R, Holbert D. Cytokine and cell adhesion molecues associated with high-intensity eccentric exercise. Eur J Appl Physiol 2000; 82(1-2): 61-7..
15. Pedersen BK, Ostrowski K, Rohde T, Bruunsgaard H. The cytokine response to strenuous exercise. Can J Physiol Pharmacol 1998; 76(5): 505-11
16. Morozov VI, Pryatkin SA, Kalinski MI, Rogozkin VA. Effect of exercise to exhaustion on myeloperoxidase and lysozyme release from blood neutrophils. *Eur J Appl Physiol*. 2003;89:257-62
17. DeVries H. A. Physiology of exercise for physical education and athletics. 2d ed. Dubuque, Iowa: C. Brown; 1974.pp.23
18. Barcroft J, Stephens J G. Observations upon the size of the spleen. Journal of Physiology 1927; 64:1 -22.
19. Niman, David C (2001)." Does exercise alters immune function and respiratory infection?" presidents council on physiol fitness and sports 3(13).
20. Ahmadizad S, El-Sayed MS. The acute effects of resistance exercise on the main determinants of blood theology. Journal of Sports Science. 2005;23:243-9.
21. Karakoc Y, Duzova H, Polat A, Emre MH, Arabac I. Effects of training period on hematological variables in regularly trained footballers. Journal of Sports Medicine .2005; 39: 4.
22. Joksimović A, Stanković D, Ilić D, Joksimović I, Milorad J. Hematological Profile of Serbian Youth National Soccer Teams. Journal of Human Kinetics. 2009; 22:51-60
23. Macintyre DL, Sorichter S, Mair J, Berg A, McKenzie DC. Markers of inflammation and myofibrillar proteins following eccentric exercise in humans. Eur J Appl Physiol. 2001 Mar; 84(3): 180-6.
24. Risoy BA, Raastad T, Hallen J, Lappegard KT, Baeverfjord K, Kravdal A, et al. Delayed leukocytosis after hard strength and endurance exercise: aspects of regulatory mechanisms. BMC Physiol. 2003; 3: 14.
25. Aaron J, Coutts, Peter R,Terrence J,Greg J,Rowsell,et al. (2007), Monitoring for overreaching in rugby league players.Eur J Appl Physiol,099:313-324
26. Simonson SR. TheImmune response to resistance exercise. J Strength Cond Res. 2001 Aug; 15(3): 378-84.
27. Mackinnon L. Exercise and immunology. Australia, Ding Park: Human kinetics publisher; 1992.pp.70-9.
28. Kendall AJ. Exercise and blood Lymphocyte subset responses. Appil. physiol .1990; 69: pp: 254- 260.
29. Murphy EA, Davis JM, Brown AS, Carmichael MD, Ghaffar A, Mayer EP. Oat beta-glucan effects on neutrophil respiratory burst activity following exercise. *Med Sci Sports Exerc*. 2007;39:639-44
30. Duclos M, Corcuff JB, Arsac L, Moreau- Gaudry F, Rashedi M, Roger P, et al. Corticotroph axis sensitivity after exercise in endurance-trained athletes. Clin Endocrinol (Oxf). 1998 Apr;48 (4):493-501.
31. Kraemer WJ, Adams EK, Cafarelli GA, Dudley C, Dooly MS, Feigenbaum SJ, et al. American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. *Med Sci Sports Exerc.* 34:364–380. 2002.

32. Nieman DC. The acute immune response to exhaustive resistance exercise. Int J Sports Med.1995;16:p:322-28

33. Ramel A, Wagner KH, Elmadfa I. Correlations between plasma noradrenaline concentrations, antioxidants, and neutrophil counts after submaximal resistance exercise in men. *Br J Sports Med*. 2004;38:e22.

34. Yamamoto Y, Nakaji S, Umeda T, Matsuzaka M, Takahashi I, Tanabe M, et al. Effects of long-term training on neutrophil function in male university judoists. *Br J Sports Med*.2008; 42:255-259.

35. Laurel T. Advances in exercise immunology. Champaing Inc., Human Kinetics.1999.

36. Morozov VI, Tsyplenkov PV, Golberg ND, Kalinski MI. The effects of high-intensity exercise on skeletal muscle neutrophil myeloperoxidase in untrained and trained rats. *Eur J Appl Physiol*. 2006; 97: 716-722

37. Suzuki K, Sato H, Kikuchi T, Abe T, Nakaji S, Sugawara K, et al. Capacity of circulating neutrophils to produce reactive oxygen species after exhaustive exercise. J Appl Physiol. 1996;81:1213-1222.

38. Frank M G, Miguel Z D, Watkins L R, Maier S F. Prior exposure to glucocorticoids sensitizes the neuro- inflammatory and peripheral inflammatory responses to E. coli lipopolysaccharide. Brain Behav Immun. 2010; 24:19–30.

39. Peake JM. Exercise-induced alterations in neutrophil degranulation and respiratory burst activity: possible mechanisms of action. Exerc Immunol Rev. 2002;8:49-100.

40. Suzuki K, Totsuka M, Nakaji S, Yamada M, Kudoh S, Liu Q, et al. Endurance exercise causes interaction among stress hormones, cytokines, neutrophil dynamics, and muscle damage. J Appl Physiol. 1999;87:1360-1367

41. Peake J, Jeremiah JP, Chris RA, Kazunori Na, Mitsuharu O, Paul BL, Katsuhiko S. Body temperature and its effect on leukocyte mobilization, cytokines and markers of neutrophil activation duringand after exercise. Eur J Appl Physiol. 2007; DOI 10.1007/s00421 -007-0598-1

42. Toby M, Jaime PC, David AJ. Exercise, heat stress and the interleukin-6 response: support for temperature-mediated neuroendocrine regulatory mechanisms. Med Sport. 2010;14 (3):96-102.

43. Katsuhiko S, Mutsuo Y, Shigeyoshi K, Noriyoshi O, Kanemitsu Y, Qiang L, et al. Circulating cytokines and hormones with immunosuppressive but neutrophil-priming potentials rise after endurance exercise in humans. Eur J Appl Physiol. 2000;81:281-287.

44. Jonsdottir IH. Effect of exercise on the immune system; neuropeptides and their interaction with exercise and immune function. Immunology and cell Biology. 2000;78:562-570.