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Effect of tomato juice consumption on the inflammatory biomarkers in male athletes following exhaustive exercise

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Objective: Strenuous exercise increases inflammatory biomarkers such as C-reactive protein (CRP) and interleukin 6 (IL-6). Dietary antioxidants can alter this inflammatory/oxidative state. The aim of this study was to determine the effect of tomato juice consumption as a rich source of lycopene (a potent antioxidant) on inflammatory biomarkers in male athletes following exhaustive exercise.
Methods: Thirty male university students were enrolled and randomly divided into two groups. The intervention group consumed 200 mL of tomato juice (containing 50 mg of lycopene) daily for one week and then performed a treadmill running exercise at 18 km/h till exhaustion. The control group consumed the same amount of water and performed the same exercise. Blood samples were collected before and immediately after exercise for analysis of IL-6, CRP, and the oxidant to antioxidant ratio. IL-6 and CRP were measured using ELISA. Oxidant to antioxidant ratio was measured with a colorimetric assay. Statistical analysis was performed using SPSS 13.
Results: The mean decrease in CRP level in the tomato juice group was significantly greater compared with the control group (-0.4 vs 0.001 mg/L, $p = 0.002$). The level of IL-6 and the oxidant to antioxidant ratio did not change after exercise in either the tomato juice or the control group.
Conclusion: Our data showed for the first time that consumption of tomato juice, which is a major source of the antioxidant lycopene, can lead to a decrease in systemic inflammation post exercise. This may present a useful approach to protecting against inflammation-induced muscle damage and to improving exercise performance in athletes.

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Introduction

Physical activity and exercise, particularly exhaustive exercise, increase oxidative stress and therefore the inflammation. Exercise increases the production of reactive oxygen species (ROS) by mitochondria of exercising muscles or by inflammatory cells such as macrophages [1, 2]. This can lead to the translocation of nuclear factor-κB (NF-κB) and consequently increase the

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secretion of inflammatory mediators, such as C-reactive protein (CRP) and interleukin (IL)-6 [1, 3]. Many studies have consistently confirmed that exercise can increase the secretion of IL-6 [4-13]. Furthermore, Studies have reported increases in plasma tumor necrosis factor (TNF)-a levels 2 hours after a 5-km run and 1 hour after the completion of a marathon [14, 15] although other studies have reported contradicting findings [5, 16]. Other studies have reported increased production of inflammatory biomarkers after different exercise challenges such as short-term intensive exercise [17, 18], resistance exercise [17, 19-21], downhill running [22, 23], intense eccentric cycling [24], and endurance running and cycling [15, 17, 18, 25-28]. This increase in the production of these cytokines during exercise may cause muscle damage [24] and therefore decrease athletic performance [29].

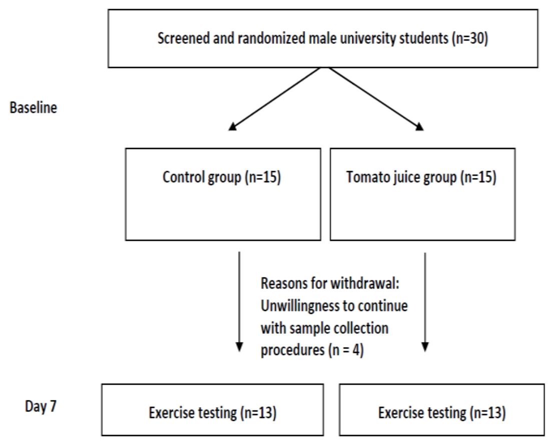
Carotenoids are natural fat-soluble compounds [30] that act as antioxidants [31]. Among them, lycopene, which can be found in high concentrations in tomatoes and tomato products [32], has the most potent antioxidant activity [33, 34]. Lycopene supplementation has been shown to decrease inflammation in vitro [35] and in vivo [35, 36] and decrease oxidative stress in living organisms [37]. We previously reported that tomato juice consumption or lycopene-rich tomato extract supplementation decreased inflammation [38, 39]. The ability of lycopene-rich tomato juice to decrease inflammation, and therefore to improve the performance of athletes, has not yet been investigated. We hypothesized that increasing the dietary intake of lycopene (as tomato juice) would reduce circulating inflammatory biomarkers in young male athletes after exhaustive exercise. The aim of this study was to determine the effect of tomato juice (and not supplement) consumption, as a rich source of lycopene (a potent antioxidant), on inflammatory biomarkers of male athletes following exhaustive exercise.

Subjects and methods

This was a randomized controlled trial with a parallel design. Thirty male students of the University of Tehran were enrolled into the study and randomly allocated to either an intervention (n = 15) or a control (n = 15) group (Figure 1). All the participants signed a consent form approved by the ethics committee of the university (ethics approval reference number: 10492). The study was supported by the Office of Vice President for Research, University of Tehran. The intervention group consumed 200 mL of tomato juice containing 56.4 mg of lycopene (pasteurized and tetrapacked tomato juice, Takdaneh Co., Tehran, Iran) daily for one week and then performed a treadmill run at 18 km/h until exhaustion. The control group consumed the same amount of drinking water and performed the same exercise. Participants with any inflammatory disease or unwilling to finish the study protocol were excluded from the study. Weight, height, age, and body mass index (BMI) were recorded for every participant. Usual daily intake of lycopene and other antioxidants were estimated using a validated semiquantitative food frequency questionnaire (FFQ). Daily intake of macronutrients was estimated using 24-hour food recall. Ten milliliters of blood was collected from each participant on two occasions (before and immediately after the exercise) for the analysis of IL-6, CRP, and the oxidant to antioxidant ratio. Blood samples were centrifuged and the serum was separated and stored at -80°C until analysis.

Biochemical assays

CRP was measured using a commercial ELISA kit according to the instructions provided by the manufacturer (Cayman Chemical Company, Michigan, US). IL-6 levels were also measured by an ELISA kit (Bender MedSystems GmbH, Vienna, Austria) according to the manufacturer’s instructions. Oxidant to antioxidant ratio was according to the method developed by Alamdari et al [40].



Statistical analysis

Differences between pre- and post-exercise values were analyzed using paired t tests or Wilcoxon tests. Between-groups differences were analyzed using independent t tests or Mann-

Whitney tests. Version 16 of SPSS software was used for the statistical analysis (SPSS for Windows; SPSS, Inc.). A p value of < 0.05 was considered statistically significant.

Results

At baseline, there were no significant differences between the intervention and control groups in age (22.6 vs 26.1 years), BMI (23.3 vs 22.6 kg/m2), weight (71.8 vs 71.5 kg), and height (Table 1). The two groups were not different in terms of daily intake of energy, macronutrients, micronutrients, carotenoids, and, specifically, lycopene (Table 2). As shown in Table 3, tomato juice consumption led to a significantly greater decrease in CRP levels in the tomato juice group compared with the control group (-0.4 vs 0.001 mg/L, p = 0.002).. This decrease in the tomato juice group was significantly different from controls. However, the mean changes in the concentration of IL-6 (0.001 vs 0.002, pg/ml) and the oxidant to antioxidant ratio were not different between the two groups (0.8 vs 1.2).

Table 1. Baseline demographic and anthropometric characteristics of the tomato juice and control groups

	Intervention group (n = 15)		Control group (n = 15)	
Variables	Mean	SEM	Mean	SEM
Age (y)	22.6	1.4	26.1	5.0
BMI (kg/m^2)	23.3	1.9	22.6	1.9
Height (cm)	175.6	4.2	177.6	6.0
Weight (kg)	71.8	7.1	71.5	7.9

No differences were observed between groups at baseline.

Discussion

This study has demonstrated, for the first time, that increased dietary intake of lycopene can lead to a reduction in systemic inflammation post exercise. We observed a decrease in circulating CRP concentrations following exercise in the group who consumed tomato juice for 7 days prior to the exercise testing. This finding suggests that increased lycopene intake may provide a strategy for protecting individuals from exercise-induced inflammation.

Lycopene is an antioxidant that is found in high concentrations in tomato juice and acts as a potent free radical scavenger [41]. It has been shown that lycopene, as well as other carotenoids, can attenuate oxidative stress and inflammation [35, 38]. Liu and colleagues showed that the consumption of tomato juice at doses ranging from 2.6 to 7.8 mg/kg for 30 days decreased oxidative stress induced by exhaustive exercise in animal subjects [41]. However, a low daily dose of 20.6 mg of lycopene for two weeks had only a minimal effect on oxidative stress in human subjects [42]. Another study also demonstrated the lack of efficacy of lycopene at low doses (30 mg/day) in reducing oxidative stress markers [43]. The dose we used in this study was around 56 mg/day, which is in between the doses used in the previous studies. This dose was chosen because it represents an amount that could be feasibly incorporated into the diet. We found that the dose we used was able to decrease CRP levels post exercise. This is an important finding as CRP is an independent predictor of the risk of myocardial infarction, stroke, and type 2 diabetes mellitus [44]. Hence, identifying strategies that minimize CRP levels are very important.

The dose of lycopene that we used in our study did not change IL-6 or antioxidant potential. While some studies have shown that consumption of fruits, vegetables, and vegetable-based products such as tomato juice can increase circulating antioxidant levels and decrease oxidant levels in the body [45, 46], others have shown that supplementation with fruit- and vegetable-derived nutrients does not decrease exercise-induced changes in the oxidant to antioxidant ratio [47-49]. In our study, the short supplementation period and the relatively small sample size may have reduced the likelihood of identifying differences in these biomarkers. In addition, it is possible that in order to provide greater protection against inflammation and oxidative stress, supplementation with higher

Table 2. Baseline dietary intake data for the tomato juice and control groups

	Tomato juice group (n = 15)		Control group (n = 15)	
Daily nutrient intake	Mean	SEM	Mean	SEM
Energy (cal)	1925	75.51	1830	62
Carbohydrate (%)*	55.2	1.1	54.1	1.0
Protein (%)*	20.1	0.6	19.5	0.5
Fat (%)*	24.71	0.8	26.4	0.8
Vitamin A (μRE)	850	35.2	915	30.5
Vitamin C (mg)	58.4	8	50.5	6
Vitamin E (mg)	8	2	8.5	1.5
Calcium (mg)	1000	120	1100	80.6
Iron (mg)	10.5	0.5	10.5	1
Selenium (µg)	65	8	62	8
Lycopene (µg)	9013	1252	9102	1321

RE = retinol equivalents

* Percentage of energy derived from each nutrient. There were no differences in baseline values between the control and the tomato juice groups.

Table 3. The effect of exercise on systemic inflammatory mediators in the tomato juice versus control groups

Inflammatory mediator	Tomato juice group (post – pre-exercise)*	Control group (post – pre-exercise)*	P value**
IL-6 (pg/mL)[a]	-0.001 ± 0.008	0.002 ± 0.010	NS
CRP (mg/L)[b]	-0.4 (-0.7, 0.0)	0.001 (0.0, 0.6)	0.002
Oxidant:antioxidant ratio[b]	0.8 (-6.5, 4.3)	1.2 (-2.4, 5.4)	NS

NS: not significant
*Analyzed using a paired *t* test or the Wilcoxon test; $p < 0.05$ for pre- vs post-exercise.
**Analyzed using an independent *t* test or the Mann-Whitney test; $p < 0.05$ for the tomato juice vs control group.
[a] Data is mean ± SD, [b] Data is median (interquartile range)

doses of lycopene may be needed.

A limitation of our study was the fact that the exercise intervention did not significantly increase inflammatory biomarkers in the control group post exercise. Many studies have indicated that physical activity, especially exhaustive exercise, increases inflammatory biomarkers and oxidative stress [1]. Inflammatory biomarkers such as IL-6 and CRP, oxidative enzymes, and the oxidant to antioxidant ratio reportedly increase during exhaustive exercise [1, 41]. For example, IL-6 increased in rats running on a treadmill at moderate intensity (70% of maximal oxygen uptake or VO2max) for 1 hour [50]. Human studies have also reported that moderate and endurance exercises increase IL-6 levels [1, 51]. This increase in IL-6 levels is also reported in marathon runners [52]. CRP is one of the acute-phase proteins whose plasma levels are elevated because of oxidative stress [53]. Taylor et al, studying 18 athletes competing in a 160-km triathlon involving canoeing, cycling, and running, found that CRP levels were raised by nearly 300% 24 hours after the race [54]. Moreover, Markovitch showed that 1, 10, 24, and 30 minutes of moderate exercise increased CRP levels [51]. However, other studies reported no increase in the inflammation following exercise in some settings [55, 56]. It appears that the exercise protocol that was used did not elicit an inflammatory response above baseline levels. Hence, the ability of the supplementation to suppress inflammation in this context was limited.

Conclusion

In conclusion, we found that a medium dose of lycopene, delivered by the consumption of tomato juice (200 mL/day), for one week suppresses post-exercise serum CRP levels but has no effect on serum IL-6 levels or the oxidant to antioxidant ratio following exhaustive exercise in male athletes. Further research is needed to determine the potential benefits of lycopene at higher doses and/or after longer durations of consumption in the post-exercise inflammation setting.

conclusion, following a healthy dietary pattern is associated with a reduced risk of MS, and adhering to a Western dietary pattern is marginally related to an increased MS risk. Further research should focus on identifying other food dietary patterns related to MS risk in order to finally establish a causal relationship between diet and MS.

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Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

1. Plunkett BA, Callister R, Watson TA, Garg ML. Dietary antioxidant restriction affects the inflammatory response in athletes. Br J Nutr. 2010;103(8):1179-84.
2. Jacob RA, Burri BJ. Oxidative damage and defense. Am J Clin Nutr. 1996;63(6):985S-90S.
3. Chew BP, Park JS. Carotenoid action on the immune response. J Nutr. 2004;134(1):257S-61S.
4. Sprenger H, Jacobs C, Nain M, Gressner AM, Prinz H, Wesemann W, et al. Enhanced release of cytokines, interleukin-2 receptors, and neopterin after long-distance running. Clin Immunol Immunopathol. 1992;63(2):188-95.
5. Ullum H, Haahr PM, Diamant M, Palmo J, Halkjaer-Kristensen J, Pedersen B. Bicycle exercise enhances plasma IL-6 but does not change

IL-1 alpha, IL-1 beta, IL-6, or TNF-alpha pre-mRNA in BMNC. Journal of Applied Physiology. 1994;77(1):93-7.
6. Drenth JP, Van Uum SH, Van Deuren M, Pesman GJ, Van der Ven-Jongekrijg J, Van der Meer JW. Endurance run increases circulating IL-6 and IL-1ra but downregulates ex vivo TNF-alpha and IL-1 beta production. J Appl Physiol (1985). 1995;79(5):1497-503.
7. Nehlsen-Cannarella S, Fagoaga O, Nieman D, Henson D, Butterworth D, Schmitt R, et al. Carbohydrate and the cytokine response to 2.5 h of running. Journal of Applied Physiology. 1997;82(5):1662-7.
8. Castell L, Poortmans J, Leclercq R, Brasseur M, Duchateau J, Newsholme E. Some aspects of the acute phase response after a marathon race, and the effects of glutamine supplementation. European journal of applied physiology and occupational physiology. 1996;75(1):47-53.
9. Rohde T, MAcLEAN DA, Richter EA, Kiens B, Pedersen BK. Prolonged submaximal eccentric exercise is associated with increased levels of plasma IL-6. American Journal of Physiology-Endocrinology And Metabolism. 1997;273(1):E85-E91.
10. Hellsten Y, Frandsen U, Orthenblad N, Sjødin B, Richter E. Xanthine oxidase in human skeletal muscle following eccentric exercise: a role in inflammation. The Journal of physiology. 1997;498(Pt 1):239-48.
11. Bruunsgaard H, Galbo H, Halkjaer-Kristensen J, Johansen T, MacLean D, Pedersen B. Exercise-induced increase in serum interleukin-6 in humans is related to muscle damage. The Journal of physiology. 1997;499(Pt 3):833-41.
12. Ostrowski K, Rohde T, Zacho M, Asp S, Pedersen B. Evidence that interleukin-6 is produced in human skeletal muscle during prolonged running. The Journal of physiology. 1998;508(3):949-53.
13. Dufaux B, Order U. Complement activation after prolonged exercise. Clinica Chimica Acta. 1989;179(1):45-9.
14. Espersen GT, Elbaek A, Ernst E, Toft E, Kaalund S, Jersild C, et al. Effect of physical exercise on cytokines and lymphocyte subpopulations in human peripheral blood. Apmis. 1990;98(1-6):395-400.
15. Ostrowski K, Rohde T, Asp S, Schjerling P, Pedersen BK. Pro-and anti-inflammatory cytokine balance in strenuous exercise in humans. The Journal of physiology. 1999;515(1):287-91.
16. Rivier A, Pene J, Chanez P, Anselme F, Caillaud C, Prefaut C, et al. Release of cytokines by blood monocytes during strenuous exercise. International journal of sports medicine. 1994;15(04):192-8.
17. Brenner I, Natale V, Vasiliou P, Moldoveanu A, Shek P, Shephard R. Impact of three different types of exercise on components of the inflammatory response. European journal of applied physiology and occupational physiology. 1999;80(5):452-60.
18. Suzuki K, Yamada M, Kurakake S, Okamura N, Yamaya K, Liu Q, et al. Circulating cytokines and hormones with immunosuppressive but neutrophil-priming potentials rise after endurance exercise in humans. European journal of applied physiology. 2000;81(4):281-7.
19. Hirose L, Nosaka K, Newton M, Laveder A, Kano M, Peake J, et al. Changes in inflammatory mediators following eccentric exercise of the elbow flexors. Exerc Immunol Rev. 2004;10(75-90):20.
20. Nieman DC, Davis J, Brown VA, Henson DA, Dumke CL, Utter AC, et al. Influence of carbohydrate ingestion on immune changes after 2 h of intensive resistance training. Journal of Applied Physiology. 2004;96(4):1292-8.
21. Smith L, Anwar A, Fragen M, Rananto C, Johnson R, Holbert D. Cytokines and cell adhesion molecules associated with high-intensity eccentric exercise. European journal of applied physiology. 2000;82(1-2):61-7.
22. Malm C, Sjödin B, Sjöberg B, Lenkei R, Renström P, Lundberg IE, et al. Leukocytes, cytokines, growth factors and hormones in human skeletal muscle and blood after uphill or downhill running. The Journal of physiology. 2004;556(3):983-1000.
23. Petersen AMW, Pedersen BK. The anti-inflammatory effect of exercise. Journal of Applied Physiology. 2005;98(4):1154-62.
24. Toft AD, Jensen LB, Bruunsgaard H, Ibfelt T, Halkjær-Kristensen J, Febbraio M, et al. Cytokine response to eccentric exercise in young and elderly humans. American Journal of Physiology-Cell Physiology. 2002;283(1):C289-C95.
25. Nieman DC, Henson DA, McAnulty SR, McAnulty LS, Morrow JD, Ahmed A, et al. Vitamin E and immunity after the Kona triathlon world championship. Medicine and science in sports and exercise. 2004;36:1328-35.
26. Peters E, Anderson R, Nieman D, Fickl H, Jogessar V. Vitamin C supplementation attenuates the increases in circulating cortisol, adrenaline and anti-inflammatory polypeptides following ultramarathon running. International journal of sports medicine. 2001;22(7):537-43.
27. Suzuki K, Nakaji S, Kurakake S, Totsuka M, Sato K, Kuriyama T, et al. Exhaustive exercise and type-1/type-2 cytokine balance with special focus on interleukin-12 p40/p70. Exercise immunology review. 2002;9:48-57.
28. Suzuki K, Nakaji S, Yamada M, Liu Q, Kurakake S, Okamura N, et al. Impact of a competitive marathon race on systemic cytokine and neutrophil responses. Medicine and science in sports and exercise. 2003;35(2):348-55.
29. Peake JM, Suzuki K, Hordern M, Wilson G, Nosaka K, Coombes JS. Plasma cytokine changes in relation to exercise intensity and muscle damage. European journal of applied physiology.

2005;95(5-6):514-21.
30. Britton G. Structure and properties of carotenoids in relation to function. The FASEB Journal. 1995;9(15):1551-8.
31. Mackinnon E, Rao A, Josse R, Rao L. Supplementation with the antioxidant lycopene significantly decreases oxidative stress parameters and the bone resorption marker N-telopeptide of type I collagen in postmenopausal women. Osteoporosis International. 2011;22(4):1091-101.
32. Tyssandier V, Feillet-Coudray C, Caris-Veyrat C, Guilland J-C, Coudray C, Bureau S, et al. Effect of tomato product consumption on the plasma status of antioxidant microconstituents and on the plasma total antioxidant capacity in healthy subjects. Journal of the American College of Nutrition. 2004;23(2):148-56.
33. Di Mascio P, Kaiser S, Sies H. Lycopene as the most efficient biological carotenoid singlet oxygen quencher. Archives of biochemistry and biophysics. 1989;274(2):532-8.
34. Stahl W, Junghans A, de Boer B, Driomina ES, Briviba K, Sies H. Carotenoid mixtures protect multilamellar liposomes against oxidative damage: synergistic effects of lycopene and lutein. FEBS letters. 1998;427(2):305-8.
35. Saedisomeolia A, Wood LG, Garg ML, Gibson PG, Wark PA. Lycopene enrichment of cultured airway epithelial cells decreases the inflammation induced by rhinovirus infection and lipopolysaccharide. The Journal of nutritional biochemistry. 2009;20(8):577-85.
36. Kim GY, Kim JH, Ahn SC, Lee HJ, Moon DO, Lee CM, et al. Lycopene suppresses the lipopolysaccharide-induced phenotypic and functional maturation of murine dendritic cells through inhibition of mitogen-activated protein kinases and nuclear factor-κB. Immunology. 2004;113(2):203-11.
37. Rousseau A-S, Hininger I, Palazzetti S, Faure H, Roussel A-M, Margaritis I. Antioxidant vitamin status in high exposure to oxidative stress in competitive athletes. British Journal of Nutrition. 2004;92(03):461-8.
38. Wood LG, Garg ML, Powell H, Gibson PG. Lycopene-rich treatments modify noneosinophilic airway inflammation in asthma: proof of concept. Free radical research. 2008;42(1):94-102.
39. Ghavipour M, Saedisomeolia A, Djalali M, Sotoudeh G, Eshraghyan MR, Malekshahi Moghadam A. Tomato juice consumption reduces systemic inflammation in overweight and obese females. Br J Nutr. 2012;15:1-5.
40. Alamdari DH, Paletas K, Pegiou T, Sarigianni M, Befani C, Koliakos G. A novel assay for the evaluation of the prooxidant–antioxidant balance, before and after antioxidant vitamin administration in type II diabetes patients. Clinical biochemistry. 2007;40(3):248-54.
41. Liu C-C, Huang C-C, Lin W-T, Hsieh C-C, Huang S-Y, Lin S-J, et al. Lycopene supplementation attenuated xanthine oxidase and myeloperoxidase activities in skeletal muscle tissues of rats after exhaustive exercise. British Journal of Nutrition. 2005;94(04):595-601.
42. Jacob K, Periago MJ, Böhm V, Berruezo GR. Influence of lycopene and vitamin C from tomato juice on biomarkers of oxidative stress and inflammation. British Journal of Nutrition. 2008;99(01):137-46.
43. Falk B, Gorev R, Zigel L, Ben-Amotz A, Neuman I. Effect of lycopene supplementation on lung function after exercise in young athletes who complain of exercise-induced bronchoconstriction symptoms. Annals of Allergy, Asthma & Immunology. 2005;94(4):480-5.
44. Bulló M, Casas-Agustench P, Amigó-Correig P, Aranceta J, Salas-Salvadó J. Inflammation, obesity and comorbidities: the role of diet. Public health nutrition. 2007;10(10A):1164-72.
45. Polidori MC, Carrillo J-C, Verde PE, Sies H, Siegrist J, Stahl W. Plasma micronutrient status is improved after a 3-month dietary intervention with 5 daily portions of fruits and vegetables: implications for optimal antioxidant levels. Nutrition journal. 2009;8(1):10.
46. Bailey DM, Lawrenson L, Mceneny J, Young IS, James PE, Jackson SK, et al. Electron paramagnetic spectroscopic evidence of exercise-induced free radical accumulation in human skeletal muscle. Free radical research. 2007;41(2):182-90.
47. MOFFARTS B, Kirschvink N, Art T, Pincemail J, Lekeux P. Effect of exercise on blood oxidant/antioxidant markers in standardbred horses: comparison between treadmill and race track tests. Equine Veterinary Journal. 2006;38(S36):254-7.
48. Sen CK. Oxidants and antioxidants in exercise. Journal of Applied Physiology. 1995;79(3):675-86.
49. Sen CK. Antioxidants in exercise nutrition. Sports Medicine. 2001;31(13):891-908.
50. SchiØtz Thorud HM, Wisløff U, Lunde P, Christensen G, Ellingsen Ø. Surgical manipulation, but not moderate exercise, is associated with increased cytokine mRNA expression in the rat soleus muscle. Acta physiologica scandinavica. 2002;175(3):219-26.
51. Markovitch D, Tyrrell RM, Thompson D. Acute moderate-intensity exercise in middle-aged men has neither an anti-nor proinflammatory effect. Journal of Applied Physiology. 2008;105(1):260-5.
52. Papassotiriou I, Alexiou V, Tsironi M, Skenderi K, Spanos A, Falagas M. Severe aseptic inflammation caused by long distance running (246 km) does not increase procalcitonin. European journal of clinical investigation. 2008;38(4):276-9.
53. Guyton AC, Hall J. Textbook of medical

physiology. 2000. WB Saunder's Co, Philadelphia.
54. Taylor C, Rogers G, Goodman C, Baynes R, Bothwell T, Bezwoda W, et al. Hematologic, iron-related, and acute-phase protein responses to sustained strenuous exercise. Journal of Applied Physiology. 1987;62(2):464-9.
55. Bruun JM, Helge JW, Richelsen B, Stallknecht B. Diet and exercise reduce low-grade inflammation and macrophage infiltration in adipose tissue but not in skeletal muscle in severely obese subjects. American Journal of Physiology-Endocrinology And Metabolism. 2006;290(5):E961-E7.
56. Gauvreau G, Wood L, Sehmi R, Watson R, Dorman S, Schleimer R, et al. The effects of inhaled budesonide on circulating eosinophil progenitors and their expression of cytokines after allergen challenge in subjects with atopic asthma. American journal of respiratory and critical care medicine. 2000;162(6):2139-44.