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Effects of Different Types Strength Exercises with Thera-Band® on Oxidative Stress and DNA Damage

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Abstract

The aim of this study is to determine the effects of both static and dynamic strength trainings on oxidative stress and DNA damage in elite boxers. 19 elite male boxers participated in the study. Boxers were instructed to perform strength exercises 3 days a week for 8 weeks. Blood samples were taken before exercises (resting), after the first exercise (acute) and after 8 weeks following the last exercise (chronic). MDA, SOD, GPx and 8-OHdG levels of blood were examined. Statistical analyses were carried out using the SPSS 22 for Windows. The data were found to not be distributed normally. Thus, Friedman, Wilcoxon and Mann-Whitney U tests were used. The results were evaluated using an alpha level of .05. In the dynamic strength exercise group, there was no significance at GPx, however MDA, SOD and 8-OHdG levels decreased in 8 weeks. In static strength exercise group, although there was no significance at SOD, GPx and 8-OHdG, MDA levels decreased both after a single session and in 8 weeks. In addition, significant difference was found between dynamic and static exercise groups at SOD, GPx and 8-OHdG levels in pre-exercise and at 8-OHdG levels after 8 weeks. Dynamic strength exercises with Thera-Band are effective on MDA, SOD and 8-OHdG chronically, static strength exercises are effective on MDA both acutely and chronically. Neither dynamic nor static strength exercises are not effective on GPx both acutely and chronically.

Keywords: antioxidant, DNA Damage, exercise, oxidative stress

1. Introduction

The effects of physical activity on human organism have been revealed in many studies. Different physiological and biochemical results can occur in human body by different forms of exercise (Gursoy et al. 2012; Aggon et al., 2017; Aggon et al., 2018). According to Galvao and Taaffe (2005), elastic band exercises are also effective on the neuromuscular system, improve the muscle strength and power (Galvao and Taaffe, 2005). Exercise can cause the formation of more free radicals by increasing metabolic processes and oxygen consumption in proportion to intensity and duration (Pereirae et al. 1994; Colakoglu et al. 1998; Palmer et al. 2003). For example, superoxide anion radicals (O2-) and hydrogen peroxide (H2O2) increase considerably in maximal exercises (Skinner et al. 1989). Free radicals, which are called as reactive oxygen species (ROS) in general, are very reactive due to these molecules having lone electrons in their outer shells. ROS are the product of normal cellular metabolism (Halliwell, 1991; Turrens, 2003; Chernyak et al. 2006). ROS may affect the structure of body lipids, proteins, carbohydrates, and DNA (Paulson, 1983). In order to prevent the formation of reactive oxygen species and damage, there is an antioxidant defense system. The increase of free radicals is controlled by the antioxidants (such as catalase, superoxide dismutase, glutathione peroxidase). In addition, the duty of antioxidants is to prevent the formation of free radical and make them ineffective (Akkus, 1995; Fisher-Wellman and Bloomer, 2009; Birben et al. 2012). Malondialdehyde (MDA) is the most abundant aldehyde product, and it is one of the markers used to measure the level of oxidative stress (Papas, 1996; Eken, 2011). Both superoxide dismutase (SOD) and glutathione peroxidase (GPx) are antioxidant enzymes. SOD catalyzes the dismutation of superoxide (O2.-) into hydrogen peroxide (H2O2), GPx catalyzes the reduction of oxidized glutathione into reduced glutathione (Michels et al. 1994; Gul et al. 2000; Yang et al. 2002). DNA is an easy target for free radicals (Dizdaroglu et al. 2002). In oxidation, one hydroxyl radical is added to 8th position of guanine molecule and 8-OHdG forms, which is one of the free radical lesions of DNA modified by oxidation (Altuntas, 2007). ROS cause break-off and base modification in DNA string. The predominant basic modification is in guanine, which is, upon oxidation, converted into 8-hydroxy-2-deoxyguanosine (8-OHdG). The resulting molecule is used as a marker for DNA damage (Loft et al. 1993; Chang et al. 2011). This study was designed to determine the effects of dynamic and static exercises with Thera-Band® on oxidative stress and DNA damage, which is a new exercise tool.

2. Method

2.1 Research Groups

Dynamic Exercise Group (DE): 10 elite boxers; 16,89±3,37 years old, 168,22±8,96 cm in length, 63,55±14,48 kg in weight and 22,29±3,42 kg/m2 in body mass index.

Static Exercise Group (SE): 9 elite boxers; 17,22±3,35 years old, 166,89±9,73 cm in length, 59,56±12,68 kg in weight and 21,19±3,36 kg/m2 in body mass index.

2.2 Experimental Design

The study was divided in two experiments (Fig. 1).

Experiment 1 was designed to evaluate the impact of oxidative stress and DNA damage for eight weeks of dynamic exercise program with Thera -Band (n = 10).

Experiment 2 was designed to evaluate the impact of oxidative stress and DNA damage for eight weeks of static exercise program with Thera -Band (n = 10).

2.3 Exercise Tool

Gold Thera-Band for very high-level resistance and silver Thera-Band for high level resistance.

2.4 Exercise Protocols

Karakurt's (2017) method was applied in two exercise- programs in this study.

Dynamic exercise program: Boxers exercised with the Thera-Band for 3 days/8 weeks. Boxers performed this sportive movement as dynamic; direct hit, crochet, uppercut, elbow flexion, elbow extension, sideways lifting, rowing up, flapping, chest press, front lift, cross-lift, cross back cut, leg press, fall off. Muscle contractions were formed by repeating each movement in this group.

Static exercise program: Boxers exercised with the Thera-Band for 3 days/8 weeks. Boxers performed this sportive movement as static; direct hit, crochet, uppercut, elbow flexion, elbow extension, sideways lifting, rowing up, flapping, chest press, front lift, cross-lift, cross back cut, leg press, fall off. Muscle contractions were stable in this group.

All movements were made at the same time in both dynamic and static groups.

2.5 Uptake and Conservation of Blood Samples

Blood samples were taken before exercises (resting), after the first exercise (acute), and after 8 weeks the last exercise (chronic). The blood samples were centrifuged at 3000 rpm for 15 minutes and they were stored at -80 ℃ for subsequent analyses.

2.6 MDA, SOD, GPx and 8-OHdG Analyses

Analysis of serum MDA was conducted by high-performance liquid chromatography (HPLC) as described by Khoschsorur et al (2000). Fluorometric detection was performed with excitation at 527nm and emission at 551nm. The peak of the MDA- TBA adduct was calibrated as 1,1,3,3 tetraethoxypropane. Standard solution was prepared through exactly the same process as with the plasma sample. MDA levels were expressed as μM.

The SOD activity was detected according to Sunet al. (1988). In this method, xanthie-xanthine oxidase complex produces super oxide radicals, which react with nitrobluetetrazolium (NBT) to form the farmasone compound. The SOD activity was measured at 560 nm by detecting the inhibition of this reaction.

GPx activity was measured by coupled spectrophotometric assay at 340 nm from the oxidation of NADPH in the presence of H2O2 used as substrate (Aebi, 1984).

Total DNA of leukocytes was extracted in accordance with Miller et al. (1988) and Adeli et al. (1990) with some modification. Nuclear fractions were obtained from 2 mL whole blood with EDTA. DNA aliquots were hydrolysed by Harparkash and Halliwell's method (Harparkash, and Halliwell, 1996). Before analysis by HPLC, they were redissolved in the eluant (final volume 1 ml). In the hydrolyzed DNA samples, 8-OHdG and dG levels were measured by HPLC with electrochemical (HPLC-ECD) and variable wavelength detector (HPLC-UV) systems as previously described (Shigenaga et al. 1994; Armstrong, 1998). The dG concentration was monitored based on absorbance (245 nm) and 8-OHdG based on the electrochemical reading (600 mV). Levels of dG and 8-OHdG were quantified using the standards of dG and 8-OHdG from sigma; the level of 8-OHdG level is expressed as the number of 8-OHdG molecules per 106 dG (Tarng et al. 2000).

2.7 Statistical Analyses

Statistical analyses were carried out using the SPSS 22 for Windows. Normalization analysis was performed to determine whether the data were normally distributed. The data were not distributed normally. Thus, K-Related Samples Friedman test was used for the analysis of repeated measurements and for the comparison of pre- and post-exercise data and chronic and acute mode data, 2-Related Samples Wilcoxon test was used in the evaluation of the groups as pairs. In addition, Mann-Whitney U test was used for inter-group comparisons. The results were evaluated on the basis of significance at 0.05.

3. Results

Table 1. Comparison of MDA, SOD, GPx and 8-OHDG Values of the DE

Parameter	Measurement	N	Min	Max	Med	Mean Rank	X2	p	Dif. Groups
MDA	Pre-Exercise (a)	10	4.78	11.32	7.59	2.00	9.800	.007*	c<b*
	Post Exercise (b)	10	6.21	13.47	11.56	2.70			
	Post 8 weeks Exercise (c)	10	3.45	8.90	6.51	1.30			
SOD	Pre-Exercise (a)	10	19.63	40.32	30.40	1.90	6.200	.045*	c<b*
	Post Exercise (b)	10	23.36	55.30	41.40	2.60			
	Post 8 weeks Exercise (c)	10	19.99	41.23	27.52	1.50			
GPx	Pre-Exercise (a)	10	41.23	124.30	63.82	1.50	4.200	.122	-
	Post Exercise (b)	10	36.95	171.90	87.90	2.10			
	Post 8 weeks Exercise (c)	10	56.32	145.20	93.63	2.40			
8-OHdG	Pre-Exercise (a)	10	.55	2.50	1.54	2.25	13.282	.001*	c<b*
	Post Exercise (b)	10	.92	3.20	1.79	2.65			
	Post 8 weeks Exercise (c)	10	.49	.98	.78	1.10			

*p≤.05 p: statistically significant different from baseline, MDA: Malondialdehyde (μM), SOD: Superoxide dismutase (IU/mL), GPx: Glutathione Peroxidase (IU/mL), 8-OHdG: 8-hydroxy-2-deoxyguanosine (pg/mL)

When Table I is examined, dynamic exercises with thera-band significantly reduced MDA, SOD and 8-OHdG values, but did not have an acute significant effect while it is seen that there is an increase in GPx values, although it does not have a significant effect at either acute or chronic level.

Table 2. Comparison of MDA, SOD, GPx and 8-OHDG Values of the SE

Parameter	Measurement	N	Min	Max	Med	Mean Rank	X2	p	Dif. Groups
MDA	Pre-Exercise (a)	9	4.21	9.21	6.35	1.67	10.889	.004*	a<b* c<b*
	Post Exercise (b)	9	6.32	16.21	10.25	2.89			
	Post 8 weeks Exercise (c)	9	3.78	8.21	5.99	1.44			
SOD	Pre-Exercise (a)	9	14.32	29.60	22.03	1.56	2.889	.236	-
	Post Exercise (b)	9	19.66	43.80	30.09	2.33			
	Post 8 weeks Exercise (c)	9	19.58	56.32	29.78	2.11			
GPx	Pre-Exercise (a)	9	36.58	101.54	49.32	1.44	4.222	.121	-
	Post Exercise (b)	9	41.63	122.30	68.21	2.33			
	Post 8 weeks Exercise (c)	9	49.63	101.25	75.32	2.22			
8-OHdG	Pre-Exercise (a)	9	.35	1.56	1,01	2.00	2.000	.368	-
	Post Exercise (b)	9	.56	1.90	.78	2.33			
	Post 8 weeks Exercise (c)	9	.41	1.02	.72	1.67			

*p≤.05 p: statistically significant different from baseline, MDA: Malondialdehyde (μM), SOD: Superoxide dismutase (IU/mL), GPx: Glutathione Peroxidase (IU/mL), 8-OHdG: 8-hydroxy-2-deoxyguanosine (pg/mL)

Table 2 examined, it was observed that static exercises performed with thera-band acutely significantly increased MDA values while they decreased them in the chronic period; it did not have an acute or chronic effect on SOD, GPx and 8-OHdG values.

Table 3. Comparison of Dynamic and Static MDA, SOD, GPx and 8-OHDG Values in Resting, a Single Session and 8 Weeks

Parameter	Measurement	Group	N	Med	Mean Rank	Sum of ranks	Z	p
MDA	Pre-Exercise	Dynamic	10	7.59	11.30	113.00	-1.061	.288
		Static	9	6.35	8.56	77.00		
	Post Exercise	Dynamic	10	11.56	10.15	101.50	-.123	.902
		Static	9	10.25	9.83	88.50		
	Post 8 weeks Exercise	Dynamic	10	6.51	10.45	104.50	-.368	.713
		Static	9	5.99	9.50	85.50		
SOD	Pre-Exercise	Dynamic	10	30.40	12.70	127.00	-2.205	.027*
		Static	9	22.03	7.00	63.00		
	Post Exercise	Dynamic	10	41.40	12.20	122.00	-1.796	.072
		Static	9	30.09	7.56	68.00		
	Post 8 weeks Exercise	Dynamic	10	27.52	9.80	98.00	-.163	.870
		Static	9	29.78	10.22	92.00		
GPx	Pre-Exercise	Dynamic	10	63.82	12.40	124.00	-1.960	.050*
		Static	9	49.32	7.33	66.00		
	Post Exercise	Dynamic	10	87.90	11.20	112.00	-.980	.327
		Static	9	68.21	8.67	78.00		
	Post 8 weeks Exercise	Dynamic	10	93.63	12.20	122.00	-1.796	.072
		Static	9	75.32	7.56	68.00		
8-OHdG	Pre-Exercise	Dynamic	10	1.54	13.10	131.00	-2.531	.011*
		Static	9	1,01	6.56	59.00		
	Post Exercise	Dynamic	10	1.79	13.10	131.00	-2.532	.011*
		Static	9	.78	6.56	59.00		
	Post 8 weeks Exercise	Dynamic	10	.78	10.10	101.00	-.082	.935
		Static	9	.72	9.89	89.00		

*p≤.05 p: statistically significant different from baseline, MDA: Malondialdehyde (μM), SOD: Superoxide dismutase (IU/mL), GPx: Glutathione Peroxidase (IU/mL), 8-OHdG: 8-hydroxy-2-deoxyguanosine (pg/mL)

In Table 3, dynamic and static exercises performed with thera-band showed significant difference in SOD, GPx and 8-OHdG values in favor of dynamic exercise group and moreover in acute 8-OHdG values significant difference was found in favor of dynamic exercise group while in chronic values no significant difference was observed on any parameter.

4. Discussion

In this study where we investigated the effects of two different types of exercises performed with thera-band on oxidative stress and DNA damage in elite boxers, both dynamic and static exercises acutely and significantly increased MDA values. In contrast, it was found that static exercises significantly decreased the values in chronic period and in in resting, acute or chronic periods, no significant difference was found between the two exercise group values.

A number of studies in the literature show that the acute effect of exercise on MDA is usually increasing intensitynm (Gullu, 2007; Akil, 2009). Lovlin et al. (1987) in exercises performed at 100% VO2Max intensity and Radak et al. (1995) in exhaustion exercises on the treadmill significant increase in lipid peroxidation values was observed. In one recent study, it was found that resistance exercises conducted for 6 months with elastic band caused oxidative stress (Franzke et al. 2018).

Another study conducted with Thera-Band suggested that both dynamic and static exercises have been reported to be significantly effective on strength values (Karakurt, 2017). Therefore, it was found that Thera-Band use has an effect on the strength and is also effective on oxidative stress.

The present study reveals that dynamic exercises significantly increased SOD values chronically while they had neither acute nor chornic effect though showing a tendency of increase. Significant difference was found in favor of dynamic exercises in values in resting while no significant difference was observed in acute and chronic periods between the groups. Moreover, when GPx values examined, they had no significant effect neither acutely nor chronically though increasing while significant difference was seen in resting values in favor of dynamic exercise groups and no significant difference was seen between the groups in acute and chronic periods.

It has been demonstrated that antioxidant system plays a more important role in the increase of oxygen consumption and the increase of oxidative stress due to the increase of oxygen consumption, both acutely or chronically (İnal et al. 2001; Burneiko et al. 2006; Celik et al. 2007; Kiyici and Kishali, 2010). In one similar study to ours, strength exercises were reported to increase SOD (Vilela et al. 2018).

8-OHdG values, another research problem, which is one of the oxidative DNA damage indicators, decreased chronically with dynamic thera-band exercises; while static exercises had no significant effect neither chronically nor acutely but the effects of dynamic and static exercises on 8-OHdG compared, no significant difference was seen in the chronic period between the groups while there were significant differences in rest and acute periods. When the literature is examined, oxidative DNA damage has been reported in some research results where the exercises are very severe (Tsakiris et al. 2006; Goon et al. 2008; Paik et al. 2009; Hamid et al. 2011). The reason could be that antioxidant mechanisms do not adequately clean free radicals in physical activities carried out in excessive concentrations. In studies where intensity is kept lower and the duration is longer, antioxidant system is more efficient and therefore more effective against oxidative DNA damage. It has been reported that traumatic acute exercises cause DNA damage but regular exercises provide protective adaptations for endogenous antioxidant defense and DNA repair mechanisms (Radak et al. 2002; Cobley et al. 2015). Hamurcu et al. (2010) reported that 8-OHdG values of athletes doing regular wrestling training were lower than the sedentary. Radak et al. (2000) reported that 8-OHdG values of the athletes who conducted a severe program showed a significant increase at the beginning but they started to decrease at the end of the program. In addition to Parisea et al. (2005) reported that the exercises they performed for 14 weeks resulted in significant decreases in the 8-OHdG amount.

5. Conclusion and Recommendations

In the present study;

- ✓ Both dynamic and static exercises performed with thera-band acutely significantly increased MDA values. However, static exercises decreased the values in the chronic period. The effects of dynamic and static exercies were found to be mostly similar in rest, acute or chronic periods.
- ✓ Dynamic exercises significantly increased SOD values chronically while static exercises had neither acute nor chronic significant effect. However, they had significant difference in favor dynamic exercise group in resting values.
- ✓ It was found that dynamic and static exercises did not have an acute or chronic effect on GPx values, and that the effects of two exercise types were significantly similar in acute and chronic periods.,
- ✓ Dynamic exercises reduce 8-OHdG values chronically, and static exercises do not have significant acute or chronic effect.

When the results obtained in the study are evaluated in general, we can state that both types of exercises conducted had significant effects on all parameters except on GPx. Today when the use of a wide variety of vehicles with different economic values has become more and more common to do exercise and the use of these ecological and easy-to-reach tools is more and more increasing. Therefore, determining the effects of such vehicles on athletes is among the primary responsibilities of researchers. Therefore, we can suggest that more effective research tools should be invented or used by the researchers.

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References

Adeli, K., & Ogbonna, G. (1990). Rapid purification of human DNA from whole blood for potential application in clinical chemistry laboratories. *Clinical chemistry*, *36*(2), 261-264.

Aebi, H. (1984). [13] Catalase in vitro. In *Methods in enzymology*, Academic Press. *105*, 121-126.

Aggon, E., Ozturk, N., Alp, H. H., Siktar, E., Agirbas, O., & Bakan, E. (2018). The effect of progresive relaxation training on free radicals, antioxidant system and oxidative dna damage, *Fresenius Environmental Bulletin*, *27(3)*, 1940-1945.

Aggon, E., Ozturk, A., Izzet, U. & Hackney, A. C. (2017). The effect of extreme sports on oxidative stress, *Archives of budo science of martial arts and extreme sports*, *13*, 85-90.

Akil, M. (2009). *Akut yuzme egzersizi yaptirilan ratlarda selenyum uygulamasinin lipit peroksidasyonu ve laktat duzeylerine etkisi*, Doctoral dissertation, Selcuk Universitesi, Saglik Bilimleri Enstitusu, Konya.

Akkus, İ. (1995). Serbest radikaller ve fizyopatolojik etkileri. *Mimoza Yayinlari, Konya*, 1-75.

Altuntas, İ. (2007). Otoimmun Tiroid Hastaliginin Tani ve Takibinde Oksidatif DNA Hasar Belirleyicisi 8-OHdG'nin Onemi. *Yuksek Lisans Tezi, Ankara Universitesi Fen Bilimleri Enstitusu, Ankara*.

Armstrong, D. (Ed.). (1998). *Free radical and antioxidant protocols* Totowa, NJ: Humana Press. 108:71-87. https://doi.org/10.1385/0896034720

Birben, E., Sahiner, U. M., Sackesen, C., Erzurum, S., & Kalayci, O. (2012). Oxidative Stress and Antioxidant Defense. *The World Allergy Organization Journal*, *5*, 9-19. https://doi.org/10.1097/WOX.0b013e3182439613

Burneiko, R. C., Diniz, Y. S., Galhardi, C. M., Rodrigues, H. G., Ebaid, G. M., Faine, L. A., ... & Novelli, E. L. (2006). Interaction of hypercaloric diet and physical exercise on lipid profile, oxidative stress and antioxidant defenses. *Food and chemical toxicology*, *44*(7), 1167-1172. https://doi.org/10.1016/j.fct.2006.01.004

Celik, A., Varol, R., Onat, T., Dagdelen, Y., & Tugay, F. (2007). Akut egzersizin futbolcularda antioksidan sistem parametrelerine etkisi. *Spormetre Beden Egitimi ve Spor Bilimleri Dergisi*, *4*, 167-172. https://doi.org/10.1501/Sporm_0000000087

Chang, F. K., Mao, I. F., Chen, M. L., & Cheng, S. F. (2011). Urinary 8-hydroxydeoxyguanosine as a biomarker of oxidative DNA damage in workers exposed to ethylbenzene. *Annals of occupational hygiene*, *55*(5), 519-525.

Chernyak, B. V., Izyumov, D. S., Lyamzaev, K. G., Pashkovskaya, A. A., Pletjushkina, O. Y., Antonenko, Y. N., ... & Skulachev, V. P. (2006). Production of reactive oxygen species in mitochondria of HeLa cells under oxidative stress. *Biochimica et Biophysica Acta (BBA)-Bioenergetics*, *1757*(5-6), 525-534. https://doi.org/10.1016/j.bbabio.2006.02.019

Cobley, J. N., Moult, P. R., Burniston, J. G., Morton, J. P., & Close, G. L. (2015). Exercise improves mitochondrial and redox-regulated stress responses in the elderly: better late than never!. *Biogerontology*, *16*(2), 249-264. https://doi.org/10.1007/s10522-014-9546-8

Colakoglu, S., Kirkali, G., Colakoglu, M., Ormen, M., & Akan, P. (1998). Egzersizde E vitamini desteginin oksidan stres ve dayaniklilik uzerine etkileri. *Klinik Gelisim*, *11*, 412-415.

Dizdaroglu, M., Jaruga, P., Birincioglu, M., & Rodriguez, H. (2002). Free radical-induced damage to DNA: mechanisms and measurement 1, 2. *Free Radical Biology and Medicine*, *32*(11), 1102-1115. https://doi.org/10.1016/S0891-5849(02)00826-2

Eken, A. (2017). rat kan ve doku orneklerinde oksidatif stres parametreleri. *Journal of Clinical and Analytical Medicine*. 69-73.

Fisher-Wellman, K., & Bloomer, R. J. (2009). Acute exercise and oxidative stress: a 30-year history. *Dynamic medicine*, *8*(1), 1. https://doi.org/10.1186/1476-5918-8-1

Franzke, B., Schober-Halper, B., Hofmann, M., Oesen, S., Tosevska, A., Henriksen, T., ... & Wagner, K. H. (2018). Age and the effect of exercise, nutrition and cognitive training on oxidative stress–The Vienna Active Aging Study (VAAS), a randomized controlled trial. *Free Radical Biology and Medicine*, *121*, 69-77. https://doi.org/10.1016/j.freeradbiomed.2018.04.565

Galvao, D. A., & Taaffe, D. R. (2005). Resistance exercise dosage in older adults: single-versus multiset effects on physical performance and body composition. *Journal of the American Geriatrics Society*, *53*(12), 2090-2097. https://doi.org/10.1111/j.1532-5415.2005.00494.x

Goon, J. A., Noor Aini, A. H., Musalmah, M., Yasmin Anum, M. Y., & Wan Ngah, W. Z. (2008). Long term Tai Chi exercise reduced DNA damage and increased lymphocyte apoptosis and proliferation in older adults. *Med J Malaysia*, *63*(4), 319-324.

Gul, M., Kutay, F. Z., Temocin, S., & Hanninen, O. (2000). Cellular and clinical implications of glutathione. *Indian journal of experimental biology*, *38*(7), 625-634.

Gullu, E., Tamer, K., Ozer, C., Gullu, A., & Cicioglu, İ. (2012). Dayaniklilik sporcularinda maksimal ve submaksimal egzersiz sonrasi olusan oksidan stres ve antioksidan duzeylerinin karsilastirilmasi. *Selcuk Universitesi Beden Egitimi ve Spor Bilim Dergisi*, *14*(2), 184-190.

Gursoy, R., Aggon, E., Stephens, R., & Ziyagil, M. A. (2012). Comparison of the physical and biomotor characteristics, and reaction time between Turkish male and female ice hockey players. *Advances in Physical Education, 2(4)*, 169-171.

Halliwell, B. (1991). Reactive oxygen species in living systems: source, biochemistry, and role in human disease. *The American journal of medicine*, *91*(3), 14-S22. https://doi.org/10.1016/0002-9343(91)90279-7

Hamid, N. A. A., Hasrul, M. A., Ruzanna, R. J., Ibrahim, I. A., Baruah, P. S., Mazlan, M., ... & Ngah, W. Z. W. (2011). Effect of vitamin E (Tri E®) on antioxidant enzymes and DNA damage in rats following eight weeks exercise. *Nutrition journal*, *10*(1), 37. https://doi.org/10.1186/1475-2891-10-37

Hamurcu, Z., Saritas, N., Baskol, G., & Akpinar, N. (2010). Effect of wrestling exercise on oxidative DNA damage, nitric oxide level and paraoxonase activity in adolescent boys. *Pediatric exercise science*, *22*(1), 60-68. https://doi.org/10.1123/pes.22.1.60

Harparkash, K. & Halliwell, B. (1996). Measurement of oxidized and methylated DNA bases by HPLC with electrochemical detection. *Biochemical Journal*, *318*(1), 21-23. https://doi.org/10.1042/bj3180021

Inal, M., AkyUz, F., Turgut, A., & Getsfrid, W. M. (2001). Effect of aerobic and anaerobic metabolism on free radical generation swimmers. *Medicine and science in sports and exercise*, *33*(4), 564-567. https://doi.org/10.1097/00005768-200104000-00009

Karakurt S. *Elit boksorlerde thera-band© ile yapilan dinamik ve statik kuvvet antrenmanlarinin motorik ozelikler uzerine etkisi*, Erzincan Universitesi, Saglik Bilimleri Enstitusu, Beden Egitimi ve Spor Anabilim Dali, Erzincan; 2017.

Khoschsorur, G. A., Winklhofer-Roob, B. M., Rabl, H., Auer, T., Peng, Z., & Schaur, R. J. (2000). Evaluation of a sensitive HPLC method for the determination of malondialdehyde, and application of the method to different biological materials. *Chromatographia*, *52*(3-4), 181-184. https://doi.org/10.1007/BF02490453

Kiyici, F., & Kishali, N. F. (2010). Alp disiplini kayakcilarinda surat egzersizleri sonrasi kan antioksidan Duzeylerinin incelenmesi. *Journal of Physical Education and Sport Sciences*, Ataturk Univetrsity, *12*(1), 1-9.

Loft, S., Fischer-Nielsen, A., Jeding, I. B., Vistisen, K., & Poulsen, H. E. (1993). 8-Hydroxydeoxyguanosine as a urinary biomarker of oxidative DNA damage. *Journal of Toxicology and Environmental Health, Part A Current Issues*, *40*(2-3), 391-404. https://doi.org/10.1080/15287399309531806

Lovlin, R., Cottle, W., Pyke, I., Kavanagh, M., & Belcastro, A. N. (1987). Are indices of free radical damage related to exercise intensity. *European journal of applied physiology and occupational physiology*, *56*(3), 313-316. https://doi.org/10.1007/BF00690898

Michiels, C., Raes, M., Toussaint, O., & Remacle, J. (1994). Importance of Se-glutathione peroxidase, catalase, and Cu/Zn-SOD for cell survival against oxidative stress. *Free radical Biology and medicine*, *17*(3), 235-248. https://doi.org/10.1016/0891-5849(94)90079-5

Miller, S. A., Dykes, D. D., & Polesky, H. F. R. N. (1988). A simple salting out procedure for extracting DNA from human nucleated cells. *Nucleic acids research*, *16*(3), 1215. https://doi.org/10.1093/nar/16.3.1215

Paik, I. Y., Jin, C. H., Jin, H. E., Kim, Y. I., Cho, S. Y., Roh, H. T., ... Suh, S. H. (2009). Effects of the NADPH oxidase p22phox C242T polymorphism on endurance exercise performance and oxidative DNA damage in response to aerobic exercise training. *Molecules and cells*, *27*(5), 557-562. https://doi.org/10.1007/s10059-009-0071-6

Palmer, F. M., Nieman, D. C., Henson, D. A., McAnulty, S. R., McAnulty, L., Swick, N. S., ... Morrow, J. D. (2003). Influence of vitamin C supplementation on oxidative and salivary IgA changes following an ultramarathon. *European journal of applied physiology*, *89*(1), 100-107. https://doi.org/10.1007/s00421-002-0756-4

Papas, A. M. (1996). Determinants of antioxidant status in humans. *Lipids*, *31*(1), 77-82. https://doi.org/10.1007/BF02637055

Parise, G., Phillips, S. M., Kaczor, J. J., & Tarnopolsky, M. A. (2005). Antioxidant enzyme activity is up-regulated after unilateral resistance exercise training in older adults. *Free Radical Biology and Medicine*, *39*(2), 289-295. https://doi.org/10.1016/j.freeradbiomed.2005.03.024

Paulson, D.R. (1983). Free-Radicals in Biology - Pryor, Wa. *J Am Chem Soc*. 105(16), 5516.

Pereira, B. C. R. L. F., Rosa, L. C., Safi, D. A., Medeiros, M. H. G., Curi, R., & Bechara, E. J. H. (1994). Superoxide dismutase, catalase, and glutathione peroxidase activities in muscle and lymphoid organs of sedentary and exercise-trained rats. *Physiology & behavior*, *56*(5), 1095-1099. https://doi.org/10.1016/0031-9384(94)90349-2

Radak, Z., Asano, K., Inoue, M., Kizaki, T., Oh-Ishi, S., Suzuki, K., ... Ohno, H. (1995). Superoxide dismutase derivative reduces oxidative damage in skeletal muscle of rats during exhaustive exercise. *Journal of applied physiology*, *79*(1), 129-135. https://doi.org/10.1152/jappl.1995.79.1.129

Radák, Z., Naito, H., Kaneko, T., Tahara, S., Nakamoto, H., Takahashi, R., … Goto, S. (2002). Exercise training decreases DNA damage and increases DNA repair and resistance against oxidative stress of proteins in aged rat skeletal muscle. *Pflugers Archiv*, *445*(2), 273-278. https://doi.org/10.1007/s00424-002-0918-6

Radák, Z., Pucsuk, J., Boros, S., Josfai, L., & Taylor, A. W. (2000). Changes in urine 8-hydroxydeoxyguanosine levels of super-marathon runners during a four-day race period. *Life sciences*, *66*(18), 1763-1767. https://doi.org/10.1016/S0024-3205(00)00499-9

Shigenaga, M. K., Aboujaoude, E. N., Chen, Q., & Ames, B. N. (1994). [2] Assays of oxidative DNA damage biomarkers 8-oxo-2′-deoxyguanosine and 8-oxoguanine in nuclear DNA and biological fluids by high-performance liquid chromatography with electrochemical detection. In *Methods in enzymology*. Academic Press, *234*, 16-33.

Skinner, J. S., Corbin, C. B., Landers, D. M., Martin, P. E., & Wells, C. L. (1989). Future Directions in Exercise and Sport Science Research. *Champaign, Illipnis, Human Kinetics Book*, 151-161.

Sun, Y. I., Oberley, L. W., & Li, Y. (1988). A simple method for clinical assay of superoxide dismutase. *Clinical chemistry*, *34*(3), 497-500.

Tarng, D. C., Huang, T. P., Wei, Y. H., Liu, T. Y., Chen, H. W., Chen, T. W., & Yang, W. C. (2000). 8-Hydroxy-2′-deoxyguanosine of leukocyte DNA as a marker of oxidative stress in chronic hemodialysis patients. *American Journal of Kidney Diseases*, *36*(5), 934-944. https://doi.org/10.1053/ajkd.2000.19086

Tsakiris, S., Parthimos, T., Parthimos, N., Tsakiris, T., & Schulpis, K. H. (2006). The beneficial effect of L-cysteine supplementation on DNA oxidation induced by forced training. *Pharmacological research*, *53*(4), 386-390. https://doi.org/10.1016/j.phrs.2006.01.008

Turrens, J. F. (2003). Mitochondrial formation of reactive oxygen species. *The Journal of physiology*, *552*(2), 335-344. https://doi.org/10.1113/jphysiol.2003.049478

Vilela, T. C., Effting, P. S., dos Santos Pedroso, G., Farias, H., Paganini, L., Sorato, H. R., ... & de Pinho, R. A. (2018). Aerobic and strength training induce changes in oxidative stress parameters and elicit modifications of various cellular components in skeletal muscle of aged rats. *Experimental gerontology*, *106*, 21-27. https://doi.org/10.1016/j.exger.2018.02.014

Yang, J., Lam, E. W. N., Hammad, H. M., Oberley, T. D., & Oberley, L. W. (2002). Antioxidant enzyme levels in oral squamous cell carcinoma and normal human oral epithelium. *Journal of oral pathology & medicine*, *31*(2), 71-77. https://doi.org/10.1034/j.1600-0714.2002.310202.x