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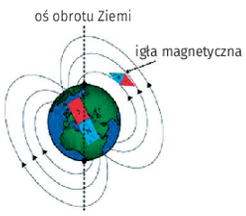

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Komentarz ten jest moim osobistym świadectwem zadowolenia z produktów biomagnetycznych „Ort Butterfly”, których używam od 20. lat! Zastanawiam się, zwłaszcza nad fenomenem poduszki (określenie nie jest przypadkowe) zwyczajnie; nie wyobrażam sobie snu i wypoczynku bez magnetycznej „Ort Butterfly” – pod głową! Jej ergonomiczny, przyjazny dla głowy i szyi kształt sprawia, że wysypiam się „po królewsku”. Zabieram ją również ze sobą w bliższe i dalsze podróże! Czyż gdyby była to zwyczajna poduszka, fundowałbym sobie dodatkowy bagaż? Wychwalam więc ją od zarania, polecam i rekomenduję, bo jest tego warta! Bez niej nie wyobrażam sobie prawdziwie relaksacyjnego snu i błogiego, kojącego wyczpoczynku! Dziękuję, że ją Pani stworzyła!

J. Szw. Działdowo (maj 2020)

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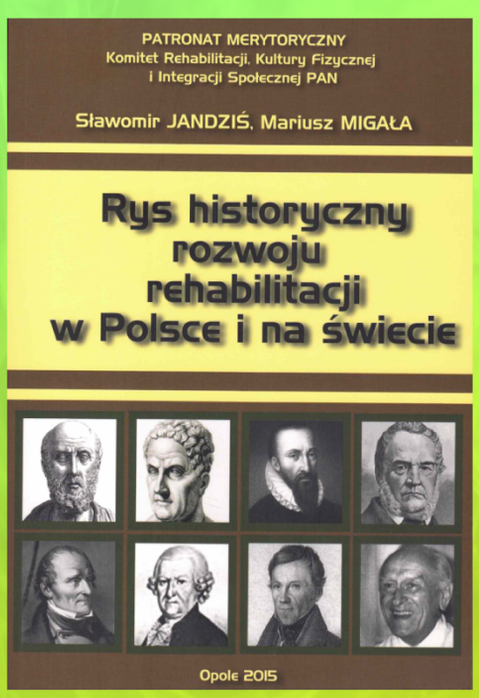

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The differences frequency of weekly physical exercise in antioxidant serum levels and muscle damage

Różnice w częstotliwości wykonywania ćwiczeń fizycznych w tygodniu oraz ich wpływ na poziom antyoksydantów w surowicy i uszkodzenia mięśni

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Abstract

Problems and Purpose. A measurable physical exercise that follows the rules can improve physiological abilities. However, physical exercise that is not according to the rules, such as lack of recovery time caused by too frequent exercise, can increase the accumulation of free radicals in the body. In addition, the limited recovery time can also increase tissue damage to the muscles. Therefore, this study aims to determine the effect of differences in the frequency of physical exercise in one week on serum antioxidant levels and tissue damage.

Materials and methods. This study was experimental with a post-test-only control group design, with the sample being male Wistar rats. There were 24 male Wistar rats divided into four groups. In the control group, the rats were not given physical exercise. In experimental group 1, rats were given physical exercise 2 times a week. In experimental group 2, rats were given physical exercise 4 times a week. In group 3, rats were given physical exercise every day. Physical training was carried out for four weeks. Then, biomarkers of serum antioxidant levels (SOD, CAT, GPx) and muscle tissue damage biomarkers (LDH, IL-6, and CPK) were checked.

Results. Physical exercise 4 times a week and daily without sufficient recovery time can significantly reduce serum antioxidant levels and increase muscle tissue damage ($p < 0.05$).

Conclusion. Based on this study, physical exercise must be accompanied by sufficient recovery time to avoid decreased serum antioxidant levels and increased muscle tissue damage.

Keywords

physical exercise, antioxsidant level, muscle damage

Streszczenie

Problemy i cel. Ćwiczenia fizyczne wykonywane zgodne z zasadami mogą poprawić zdolności fizjologiczne. Jednak ćwiczenia fizyczne wykonywane niezgodnie z zasadami, czyli brak odpowiedniego czasu na regenerację spowodowany zbyt częstymi ćwiczeniami, mogą zwiększać gromadzenie się wolnych rodników w organizmie. Ponadto ograniczony czas regeneracji może również zwiększyć uszkodzenie tkanki mięśniowej. Dlatego niniejsze badanie ma na celu określenie wpływu różnic w częstotliwości wykonywania ćwiczeń fizycznych w ciągu jednego tygodnia na poziom antyoksydantów w surowicy i uszkodzenie tkanek.

Materiał i metody. Było to badanie eksperymentalne z grupą kontrolną, które objęło samce szczurów Wistar. 24 samce szczurów Wistar podzielono na cztery grupy. W grupie kontrolnej szczury nie wykonywały ćwiczeń fizycznych. W grupie eksperymentalnej 1 szczury wykonywały ćwiczenia fizyczne dwa razy w tygodniu. W grupie eksperymentalnej 2 szczury wykonywały ćwiczenia fizyczne cztery razy w tygodniu. W grupie eksperymentalnej 3 szczury wykonywały ćwiczenia fizyczne codziennie. Trening fizyczny prowadzono przez cztery tygodnie. Następnie sprawdzono biomarkery poziomu antyoksydantów w surowicy (SOD, CAT, GPx) oraz biomarkery uszkodzenia tkanek mięśniowych (LDH, IL-6 i CPK).

Wyniki. Ćwiczenia fizyczne wykonywane cztery razy w tygodniu i codziennie bez wystarczającego czasu na regenerację mogą znacznie obniżyć poziom antyoksydantów w surowicy i zwiększyć uszkodzenie tkanek mięśniowych ($p < 0,05$).

Wniosek. Na podstawie tego badania, wysiłkowi fizycznemu musi towarzyszyć wystarczający czas regeneracji, aby uniknąć obniżenia poziomu antyoksydantów w surowicy i zwiększonego uszkodzenia tkanek mięśniowych.

Słowa kluczowe

wysiłek fizyczny, poziom antyoksydantów, uszkodzenia mięśni

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Introduction

Exercise has long been used to raise the caliber of human resources. Measurable, consistent, and planned exercise can benefit the health and functionality of many different bodily systems [1]. Exercise must be done considering the guiding principles of an effective exercise program [2]. WHO advises engaging in 150 minutes of physical activity weekly to maintain overall health and fitness [3]. However, they frequently made mistakes when putting physical exercise into practice. Exercise that disregards the fundamentals of exercise will be harmful to your health. This is due to the fact that exercise is a stressor with a variety of negative side effects. Exercise can disrupt the body's homeostasis, alter the physical environment, and alter the chemical composition of cells. Exercise can raise body temperature, make blood more acidic, and deplete the body's oxygen supply [4].

Several researchers have noted that strenuous exercise can cause tissue damage. An increase in intracellular enzyme levels in the serum causes tissue damage brought on by exercise [5]. The cell membrane is harmed as a result, and cell membrane permeability increases. The free radical theory is one theory that can account for the occurrence of tissue destruction in the body following exercise [6]. Free radicals are being studied more and more by scientists all over the world because it is thought that their activity is the root cause of many pathological conditions, including cardiovascular, cancerous, respiratory, and ageing processes [7].

Aerobic organisms will continually produce free radicals. Adenosine triphosphate, or ATP, is produced by aerobic organisms using oxygen. In typical conditions, 3-5% of oxygen is transformed into reactive oxygen compounds [8]. The production of reactive oxygen compounds can increase several times over normal conditions under specific conditions, such as demanding work, strenuous exercise, or other stressful situations. Exercise has been shown to increase antioxidants like superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx) in certain doses, according to a number of studies. However, there is also evidence to suggest that during strenuous exercise, harm starts when the body's production of antioxidant enzymes like superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx) declines [9].

Strenuous physical exercise can also increase inflammation in muscle cells. During strenuous physical exercise involving continuous muscle contractions, it can eventually lead to muscle damage [10]. Intramuscular inflammation is a coordinated process that leads to cellular adaptation processes such as skeletal muscle hypertrophy. Small damage or commonly known as microtrauma to the muscles, is one of the triggers for the inflammatory response [11]. This damage can stimulate the release of proinflammatory mediators such as cytokines (TNF-α, IL-1, and IL-6) by macrophages during strenuous exercise [12]. This muscle cell damage is usually indicated by the release of creatine phosphokinase (CPK) and other markers of damage, for example, myoglobin and lactic acid dehydrogenase (LDH), in the bloodstream [13]. Muscle damage during physical exercise occurs in the sarcomeres, cytoskeleton, and sarcolemma, which causes a temporary loss of muscle strength and causes delayed onset muscle soreness (DOMS) [14]. This muscle tissue damage will increase in relation to the dose of exercise (frequency, intensity, time, and type) and oxygen consumption during exercise [15].

The latest research from Bernat et al., published in 2019, stated an increase in lactic acid dehydrogenase, creatine phosphokinase, and c-reactive protein in marathon athletes participating in a marathon training event in the city of Valencia with a sample of 86 runners. In this study, dehydrogenated lactic acid would increase shortly after completing the Matarhon, decrease slowly after 24 hours, and return to normal after 192 hours. In this research, creatine phosphokinase and c-reactive protein showed different results. CPK experienced a peak increase after 24 hours of completing the marathon and returned to normal after 192 hours. Long-term recovery can restore CPK, LDH, and CRP levels [16].

The study of the determination of the dose of physical exercise is still very interesting research to do. Research with experimental animals or athletes regarding doses of physical exercise is still being tested frequently. Not only to improve sports performance, but research on doses of physical exercise is also often carried out for the process of improving body physiology, improving the quality of health, and improving the quality of life. Not only through research that looks at functional abilities but research that looks at aspects of molecular biology must also be carried out and developed. Therefore, it is necessary to study the frequency of physical exercise every week on antioxidant levels in the body in terms of SOD, CAT, and GPx enzyme levels and damage to muscle tissue in terms of IL-6, CPK, and LDH.

Method

Study Design

This is an experimental laboratory study using experimental animals with a post-test group control design to see the effect of differences in the frequency of physical exercise in one week on SOD, CAT, and GPx antioxidant levels and muscle tissue damage in terms of IL-6, CPK, and LDH.

This research was conducted at the Integrated Biomedical Laboratory (IBL) Faculty of Medicine, Sultan Agung Islamic University, Semarang, Indonesia, and the Center for Food and Nutrition Studies, Gadjah Mada University, Indonesia. The medical ethics committee has approved this research from Sultan Agung Islamic University, Semarang. The ethical clearance number for this research is No.358/X/2022/Bioethics Commission. This research was conducted for four weeks conducted, from November 2022-February 2023.

Participants

This study used male rats aged 8-10 weeks with the Wistar strain. Rats must be healthy, weighs 150-200 grams, and has a good appetite. This study consists of 4 groups. Determination of the minimum number of subjects is determined based on Federer's formula, namely (n-1) x (t-1) 15, in which n is the sample size for each group. At the same time, t is the number of groups so that n 6 is obtained. The rat samples were obtained from the experimental animal laboratory of the Faculty of Medicine, Sultan Agung Islamic University, Semarang.

Treatment of animals samples

The procedure of this study begins with the acclimation for seven days with the standard feed and distilled water. Before exercising, the rats were initially checked for weight.

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Different approaches were used with each of the 4 research groups. Rats in the control group received only a regular diet and no physical activity. Rats in the first treatment (G1) group received regular food and underwent physical activity two times per week for four weeks. Rats in the second treatment (G2) group received regular food and four times per week of physical activity over a period of four weeks. Rats were given regular food and exercised seven times per week for a total of four weeks in the third treatment group (G3).

Figure 1. Swimming exercise in rats

Physical exercise is given by means of swimming exercises. Swimming practice is done in the morning. Preparation for swimming practice begins with filling the aquarium with a 70-80 cm water level. The water temperature in the aquarium was 36°C, and then the rats were put into the aquarium, and the rats swam for 25-40 minutes until they got tired, the signs that they were almost drowning [17, 18].

Procedure Blood Sampling

Sampling was carried out in the orbital sinus of the eye. All groups had blood taken on the 29th day. Then the blood sample was put into a vacutainer tube and put into a centrifuge machine. Centrifuge at 3000 rpm for 30 minutes to obtain blood serum. Then the blood sample is put into a micro-tube, placed, and stored in a cooler with a temperature of −20°C [19].

Procedure for checking Superoxide Dismutase (SOD) levels

Superoxide dismutase levels were determined biochemically using the Ran-SOD BioVision Colorimetric Assay Kit at the Centre for Food and Nutrition Studies, Gadjah Mada University, Indonesia. The reagents in this kit consist of a mixed substrate containing xanthine, phosphate buffer to dilute (the standard or sample), xanthine oxidase, and the standard solution to create the standard curves. A total of 25 µL of plasma was used to measure blood SOD levels. Initially, 25 µL of the sample was put into the cuvette, and 850 µL of the mixed substrate was added and mixed well. To inhibit SOD, 5 µL of 5 mM sodium cyanide was added to the mixture until it was properly mixed. After that, 125 µL of xanthine oxidase was added. The absorption was read at a wavelength of 505 nm with a spectrophotometer (Genesis). Superoxide dismutase (SOD) levels were determined using the equation obtained from the standard curve [20].

Procedure for checking Catalase (CAT) levels

The catalase biomarker (CAT) was examined using a basic biomedical rosette technique with a spectrophotometer at the Centre for Food and Nutrition Studies, Gadjah Mada University. The first way to check for catalase is with blood serum taken from the orbital sinuses of rats, as much as 1 mL. Then, 900µL of 0.55 triton X-100 solution was added to 200µL of serum to make lysate. Then prepare a standard solution by dissolving 9.5 mL of phosphate buffer in the mother liquor. Next, add 12.5 mL phosphate buffer to 10 µL and 1 mL H_2O_2. After that, vortexing and a spectrophotometer with a wavelength setting of 240 nm and a time lag of 15 seconds, 30 seconds, 45 seconds, and 60 seconds.

Procedure for checking Glutathione Peroxidase (GPx) levels

The glutathione peroxidase (GPx) biomarker was examined using a basic biomedical rosette technique with a spectrophotometer at the Centre for Food and Nutrition Studies, Gadjah Mada University. The first way to check for catalase is with blood serum taken from the orbital sinuses of rats, as much as 1 mL. Then to 200 µl sample was added 200 µl 0.1 M phosphate buffer pH 7.0, which contained 0.1 mM EDTA, 200 µl reduced glutathione (GSH), 10 mM, and 200 µl glutathione reductase enzyme (2.4 units). Incubate for 10 minutes at 37°C. Then 200 µl NADPH 1.5 mm was added, then incubated again for 3 minutes at the same temperature. Then incubated again for 3 minutes at the same temperature. Then the absorbance was measured between 1 to 2 minutes with a spectrophotometer at a wavelength of 340 nm.

Procedure for checking Lactic Acid Dehydrogenase (LDH) levels

The lactic acid dehydrogenase (LDH) biomarker was examined using a basic biomedical rosette technique with ELISA at the Centre for Food and Nutrition Studies, Gadjah Mada University. The first way to check for catalase is with blood serum taken from the orbital sinuses of rats, as much as 1 mL. LDH levels are the results of measurements of the Lactate Dehydrogenase enzyme from laboratory tests using the DGKC Optimised testing method, with normal values of 250-450 U/L.

Procedure for checking Interleukin-6 (IL-6) levels

50 µl of diluent was added to all wells. Then 50 µl of standard, control, and sample were added to each well and mixed gently for 1 minute. Covered with adhesive and incubated for 2 hours at room temperature. Each well was aspirated and washed 5 times. Washing was carried out with a 400 µl wash buffer. Next,

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100 µl of Rat IL-6 conjugate was put into each well, covered with adhesive, and incubated for 2 hours at room temperature. Then repeat the washing 5 times. Added 100 µl of substrate solution to each well and incubated for 30 minutes at room temperature. Then 100 µl stop solution was added to each well and mixed. Within 30 minutes, it was read at a wavelength of 450 nm.

Procedure for checking Creatine Phospokinase (CPK) levels

The process of examining creatine phosphokinase consists of several stages. First, prepare all the tools and muscle blood samples. Next, make solutions of monoreagents 1 and 2 by adding 2.5 ml of monoreagent 1 to the monoreagent. CPK activity was measured at 25°C. Next, 40 µL of homogenate was mixed with 1.0 mL of monoreagentt. Incubate for 3 minutes. Read the absorbance at 1, 2, and 3 minutes at a wavelength of 340 nm.

Statistical Analysis

All values were reported as mean ± standard deviation (SD). Statistical analysis was done using SPSS version 26 with one-way analysis of variance (ANOVA) and using the post-hoc test. Statistical significant level was considered at $P < 0.05$.

Results

Four groups were created out of a sample of 24 male rats that fit the inclusion and exclusion criteria. Each group received a unique course of treatment. Rats in the control group received only standard feedings and no physical activity. Two times per week, rats in experimental group 1 received physical activity. In contrast, rats in experimental group 2 received physical activity four times per week. Rats in experimental group 3 received physical activity seven times per week. Exercise is prescribed for four weeks, or 28 days. Blood samples were taken from all groups on the 29th day. After that, SPSS was used to process and analyse the research findings.

Table 1. Research data and ANOVA test results

Variable	Mean (SD)	Range	Shapiro-Wilk	P-value
SOD group control	78.98 ± 4.93	71.43–85.71	0.979	
SOD group experiment 1	82.38 ± 1.92	79.21–84.88	0.891	0.000
SOD group experiment 2	68.22 ± 3.61	64.47–73.28	0.830	
SOD group experiment 3	31.93 ± 3.53	28.57–35.71	0.451	
CAT group control	5.87 ± 0.18	5.60–6.07	0.786	
CAT group experiment 1	5.95 ± 0.33	5.75–6.23	0.845	0.000
CAT group experiment 2	4.60 ± 0.22	4.33–4.96	0.433	
CAT group experiment 3	1.72 ± 0.05	1.65–1.78	0.438	
GPx group control	71.68 ± 2.08	68.68–74.08	0.788	
GPx group experiment 1	71.47 ± 1.48	69.91–73–54	0.302	0.000
GPx group experiment 2	60.79 ± 2.69	57.11–64.51	0.983	
GPx group experiment 3	22.06 ± 1.51	20.16–24.22	0.954	
LDH group control	152.83 ± 11.62	141–178	0.758	
LDH group experiment 1	181.00 ± 15.52	174–199	0.498	0.000
LDH group experiment 2	303.17 ± 28.73	289–317	0.630	
LDH group experiment 3	738.33 ± 21.07	714–771	0.930	
IL-6 group control	26.60 ± 0.70	26.24–27.21	0.696	
IL-6 group experiment 1	31.24 ± 2.19	28.55–33.11	0.478	0.000
IL-6 group experiment 2	42.83 ± 3.29	39.67–48.27	0.489	
IL-6 group experiment 3	60.72 ± 1.22	59.38–62.69	0.672	
CPK group control	92.73 ± 7.20	84.22–104.12	0.872	
CPK group experiment 1	132.65 ± 16.96	105.84–155.34	0.758	0.000
CPK group experiment 2	374.95 ±33.21	327.88–419.33	0.948	
CPK group experiment 3	545.18 ±21.54	525.85–585.54	0.282	

Superoxide Dismutase (SOD) levels

All groups were found to be normally distributed by the Shapiro-Wilk test for superoxide dismutase (SOD) normality test results in the control group, experimental group 1, experimental group 2, and experimental group 3. Results of the Shapiro-Wilk test with a significance value of > 0.05 support this. The data were then examined using a one-way ANOVA to determine its impact. The one-way ANOVA test results had a

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significance level of 0.00. This demonstrates that there are sizable differences in the influence of various groups.
In this study, providing physical exercise 4 times per week and every day without any rest time significantly reduced SOD levels ($p < 0.05$) in the control group and the group that was given physical exercise 2 times per week. In the control group, the average SOD level was 78.98 U/mL. Then in experimental group 1, the rat group that was given physical exercise twice a week had a SOD level of 82.38 U/mL. Whereas in experimental group 2, the group of rats that were given physical exercise 4 times a week saw a decrease in SOD levels. In experimental group 2, the SOD level was 68.22 U/ml. In experimental group 3, the group of rats that were given physical exercise every day or seven times a week experienced a very drastic decrease. In experimental group 3, the SOD level was 31.93 U/mL. The difference in the average SOD level for each group can be seen in Figure 2.
Values are represented as Mean± Standard error of mean (SEM) (n = 6). ANOVA followed by Post Hoc Analysis by SPSS 26. *P < 0.05 has significant diferent SOD levels with control group. **P < 0.05 has significant diferent SOD levels with experiment group 1. ***p < 0.05 has significant diferent SOD levels with experiment group 2.

Catalase (CAT) levels
The results of the normality test using the Shapiro-Wilk test for catalase (CAT) in the control group, experimental group 1, experimental group 2, and experimental group 3 proved that all groups were normally distributed. This is indicated by the results of the Shapiro-Wilk test with a significance value of < 0.05. Then, the data was tested for the effect of using one-way ANOVA. The results of the one-way ANOVA test obtained a significance value of 0.00. This proves that there are significant differences in influence between one group and another.
In this study, providing physical exercise 4 times per week and every day without any rest time significantly reduced CAT levels ($p < 0.05$) in the control group and the group that was given physical exercise 2 times per week. In the control group, the average SOD level was 5.87 U/mL. Then in experimental group 1, the rat group that was given physical exercise twice a week had a CAT level of 5.95 U/mL. Whereas in experimental group 2, in the group of rats that were given physical exercise 4 times a week, there was a decrease in CAT levels. In experimental group 2, the CAT level was 4.60 U/ml. In experimental group 3, the group of rats that were given physical exercise every day or seven times a week experienced a very drastic decrease. In experimental group 3, the CAT level was 1.72 U/mL. The difference in the average CAT level for each group can be seen in Figure 3.

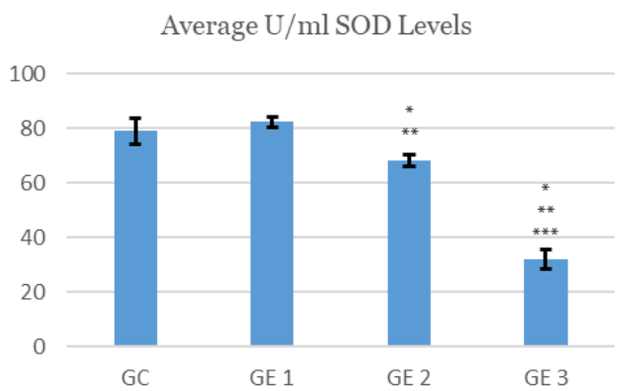

Figure 2. Effect of physical exercise on levels of superoxide dismutase (SOD)

*Values are represented as Mean± Standard error of mean (SEM) (n = 6). ANOVA followed by Post Hoc Analysis by SPSS 26. *P < 0.05 has significant diferent SOD levels with control group. **P < 0.05 has significant diferent SOD levels with experiment group 1. ***p < 0.05 has significant diferent SOD levels with experiment group 2.*

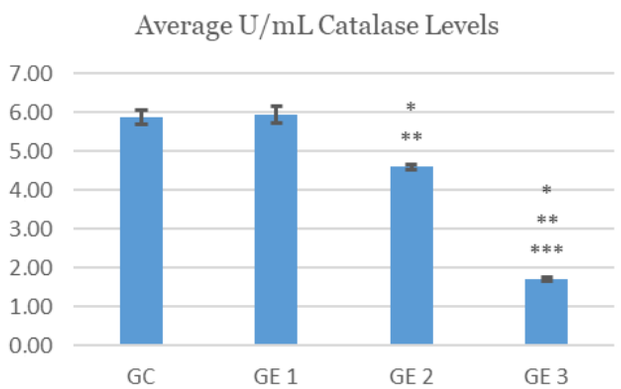

Figure 3. Effect of physical exercise on catalase levels (CAT)

*Values are represented as Mean± Standard error of mean (SEM) (n = 6). ANOVA followed by Post Hoc Analysis by SPSS 26. *P < 0.05 has significant diferent CAT levels with control group. **P < 0.05 has significant diferent CAT levels with experiment group 1. ***p < 0.05 has significant diferent CAT levels with experiment group 2.*

Glutathione Peroxidase (GPx) levels
The results of the normality test using the Shapiro-Wilk test for glutathione peroxidase (GPx) in the control group, experimental group 1, experimental group 2, and experimental group 3 proved that all groups were normally distributed. This is indicated by the results of the Shapiro-Wilk test with a significance value of < 0.05. Then, the data were tested for the effect of using one-way ANOVA. The results of the one-way ANOVA test obtained a significance value of 0.00. This proves that there are significant differences in influence between one group and another.
In this study, providing physical exercise 4 times per week and every day without any rest time significantly reduced GPx levels ($p < 0.05$) in the control group and the group that was given physical exercise 2 times per week. In the control group, the average GPx level was 71.68 U/mg. Then in experimental group 1, the group of rats that were given physical exercise twice a week had a GPx level of 71.47 U/mg. Whereas in experimental group 2, the group of rats that were given physical exercise 4 times a week saw a decrease in GPx levels. In experimental group 2, the GPx level was 60.79 U/mg. In experimental group 3, the group of rats that were given physical exercise every day or seven times a week experienced a very drastic decrease. In experimental group 3, the GPx level was 22.06 U/mg. The difference in the average GPx levels for each group can be seen in Figure 4.

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Lactic Acid Dehydrogenase (LDH) levels

The results of the normality test using the Shapiro-Wilk test for lactic acid dehydrogenase (LDH) in the control group, experimental group 1, experimental group 2, and experimental group 3 proved that all groups were normally distributed. This is indicated by the results of the Shapiro-Wilk test with a significance value of < 0.05. Then, the data were tested for the effect of using one-way ANOVA. The results of the one-way ANOVA test obtained a significance value of 0.00. This proves that there are significant differences in influence between one group and another.

In this study, providing physical exercise 4 times per week and every day without any rest time significantly reduced LDH levels ($p < 0.05$) in the control group and the group that was given physical exercise 2 times per week. In the control group, the average LDH level was 152.83 UI/L. Then in experimental group 1, the rat group that was given physical exercise twice a week had an LDH level of 181 UI/L. Whereas in experimental group 2, in the group of rats that were given physical exercise 4 times a week, there was an increase in LDH levels.Experimental group 2 had an LDH level of 303.17 UI/L.In experimental group 3, the group of rats that were given physical exercise every day or seven times a week experienced a very drastic increase. In experimental group 3, the LDH level was 738.33 UI/L. Differences in the average levels of LDH for each group can be seen in Figure 5.

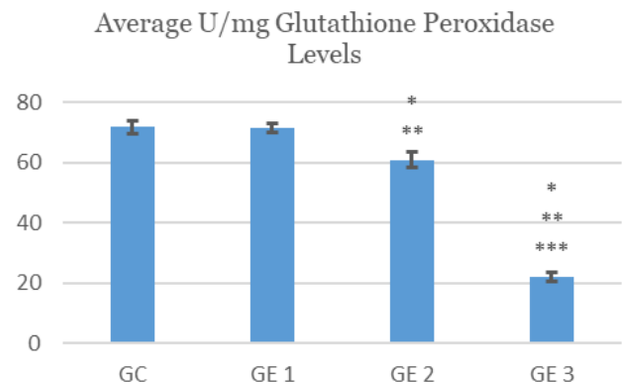

Figure 4. Effect of physical exercise on Glutathione Peroxidase (GPx) levels

*Values are represented as Mean± Standard error of mean (SEM) (n = 6). ANOVA followed by Post Hoc Analysis by SPSS 26. *P < 0.05 has significant diferent GPx levels with control group. **P < 0.05 has significant diferent GPx levels with experiment group 1. ***p < 0.05 has significant diferent GPx levels with experiment group 2.*

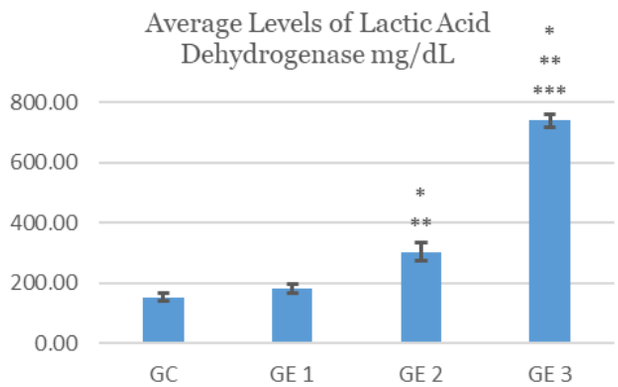

Figure 5. Effect of physical exercise on levels of Lactic Acid Dehydrogenase (LDH)

*Values are represented as Mean± Standard error of mean (SEM) (n = 6). ANOVA followed by Post Hoc Analysis by SPSS 26. *P < 0.05 has significant diferent LDH levels with control group. **P < 0.05 has significant diferent LDH levels with experiment group 1. ***p < 0.05 has significant diferent LDH levels with experiment group 2.*

Interleukin-6 (IL-6) levels

The results of the normality test using the Shapiro-Wilk test for interleukin-6 (IL-6) in the control group, experimental group 1, experimental group 2, and experimental group 3 proved that all groups had a normal distribution. This is indicated by the results of the Shapiro-Wilk test with a significance value of < 0.05. Then, the data was tested for the effect of using one-way ANOVA. The results of the one-way ANOVA test obtained a significance value of 0.00. This proves that there are significant differences in influence between one group and another.

In this study, providing physical exercise 4 times per week and every day without any rest time significantly reduced IL-6 levels ($p < 0.05$) in the control group and the group that was given physical exercise 2 times per week. In the control group, the average IL-6 level was 26.60 pg/mL.Then in experimental group 1, the rat group that was given physical exercise twice a week had an IL-6 level of 31.24 pg/mL.Whereas in experimental group 2, in the group of rats that were given physical exercise 4 times a week, there was an increase in IL-6 levels.Experimental group 2 had IL-6 levels of 42.83 pg/mL.In experimental group 3, the group of rats that were given physical exercise every day or seven times a week experienced a very drastic increase. In experimental group 3, IL-6 levels were 60.72 pg/mL. The difference in the average IL-6 levels for each group can be seen in Figure 6.

Creatine Phospokinase (CPK) levels

The results of the normality test using the Shapiro-Wilk test for creatine phosphokinase (CPK) in the control group, experimental group 1, experimental group 2, and experimental group 3 proved that all groups were normally distributed. This is indicated by the results of the Shapiro-Wilk test with a significance value of < 0.05. Then, the data were tested for the effect of using one-way ANOVA. The results of the one-way ANOVA test obtained a significance value of 0.00. This proves that there are significant differences in influence between one group and another.

In this study, providing physical exercise 4 times per week and every day without any rest time significantly reduced CPK levels ($p < 0.05$) in the control group and the group that was given physical exercise 2 times per week. In the control group, the average CPK level was 92.73 UI/L. Then in experimental group 1, the rat group that was given physical exercise twice a week had a CPK level of 113.65 UI/L. Whereas in experimental group 2, the group of rats that were given physical exercise 4 times a

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week increased CPK levels.In experimental group 2, the CPK level was 374.95 UI/L.In experimental group 3, the group of rats that were given physical exercise every day or seven times a week experienced a very drastic increase .In experimental group 3, the CPK level was 545.18 UI/L. The difference in the average CPK levels for each group can be seen in Figure 7.

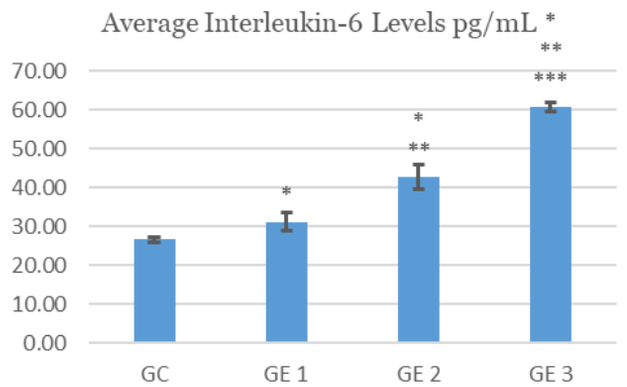

Figure 6. Effect of physical exercise on levels of Interleukin-6 (IL-6)

*Values are represented as Mean± Standard error of mean (SEM) (n = 6). ANOVA followed by Post Hoc Analysis by SPSS 26. *P < 0.05 has significant diferent IL-6 levels with control group. **P < 0.05 has significant diferent IL-6 levels with experiment group 1. ***p < 0.05 has significant diferent IL-6 levels with experiment group 2.*

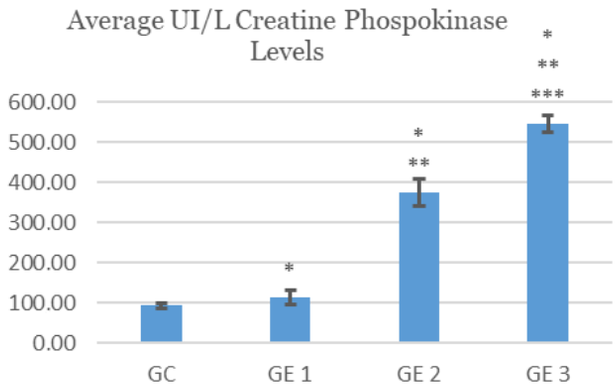

Figure 7. Effect of physical exercise on Creatine Phospokinase (CPK) levels

*Values are represented as Mean± Standard error of mean (SEM) (n = 6). ANOVA followed by Post Hoc Analysis by SPSS 26. *P < 0.05 has significant diferent LDH levels with control group. **P < 0.05 has significant diferent LDH levels with experiment group 1. ***p < 0.05 has significant diferent LDH levels with experiment group 2.*

Discussion

Physical exercise will affect the human physiological system. Several studies have shown that physical exercise can increase the inflammatory response and cause massive muscle damage, especially when done at high-intensity levels [21]. Many studies have reported that acute aerobic exercise contributes to oxidative stress. Although some studies consider that an increased inflammatory biomarker response is a sign of massive tissue damage, in trained athletes and athletes who adhere to the principles of physical training, an increased biomarker response is just a post-exercise physiological response that can return to normal after a few days of rest, right time and diet [22].

There is a mechanism linking acute physical exercise and oxidative stress to increased pro-oxidant activity through a mass action effect when the intensity is elevated and decreased resting time and inadequate antioxidant activity relative to pro-oxidants [17]. Antioxidant enzymes can be activated selectively during acute bouts of exercise depending on the oxidative stress imposed on specific tissues as well as the intrinsic antioxidant defense capacity [23]. Skeletal muscle can experience greater levels of oxidative stress during exercise than the liver and heart because of the marked increase in ROS production. In contrast, SOD, CAT, and GPx provide the main defense against ROS generated during exercise [24].

The high reactivity of free radicals makes their direct detection in humans difficult. Consequently, most studies have examined markers of lipid peroxidation, protein oxidation, cellular redox status, and changes in antioxidant enzyme activity as indirect measures of the involvement of free radicals in tissue damage [25].

The intracellular antioxidant markers SOD, CAT, and GPx demonstrate antioxidant defense against pro-oxidant activity [26]. In addition to the various and complex metabolic stressors that various levels of exercise intensity elicit, various exercise frequencies result in various antioxidant enzyme activity responses [27]. A number of variables, including oxygen consumption during exercise, dietary antioxidant intake, plasma fat content, and, most importantly, the length of recovery time, may be associated with different frequencies of post-exercise antioxidant enzyme activity [28]. Several factors may contribute to the levels of oxidative stress, so it is important to investigate the impact of exercise frequency on antioxidant enzyme activity [29].

Changes in exercise affect antioxidant enzyme activity. Exercise can easily result in an increase in total body oxygen consumption of 10 times or more. Energy demand and heat production will rise as exercise intensity and frequency rise [30]. ROS O2-, H_2O_2, and OH can be produced when there is a reduction in oxygen to water due to increased energy demand and heat production [31]. On the other hand, a greater frequency of physical activity will result in a shorter recovery period, allowing for a greater increase in oxygen consumption and ROS production [9].

In most cell types, including erythrocytes, the enzymes SOD, CAT, and GPx are the most dominant antioxidant enzymes. SOD catalyzes the formation of O_2- to H_2O_2. SOD is considered a first-line antioxidant defense system against cellular oxidants, while CAT complements the antioxidant function of SOD [24]. CAT complements the SOD antioxidant defense process by converting the remaining oxidant species into non-reactive H2O [32]. GPx is likely a cell's next response mechanism when SOD and CAT fail to meet the body's cellular antioxidant needs, such as during high-intensity exercise [33].

Several studies have investigated the acute or chronic effects of exercise on antioxidant enzymes as well as muscle tissue damage [34], but no study has investigated the effect of differences in

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exercise frequency specifically. In this study, the subjects did physical exercise at three different frequencies. The protocol used in this study controlled for exercise time and exercise frequency in one week (2 times in one week, 4 times in one week, and 7 times in one week).

The results of this study, when viewed from the levels of superoxide dismutase, glutathione peroxidase, and catalase. After physical exercise with a frequency of 2 times a week, SOD levels actually increased when compared to the control gro54up, which was not given physical exercise. Although the increase was not significant, the increase in superoxide dismutase levels was due to the fact that SOD is the first-line antioxidant defense system against cellular oxidants and is a major factor in avoiding the increase in lipoperoxidation expected from physical exercise [24].

The results of the ANOVA test also revealed significant changes in SOD, CAT, and GPx activity after exercise, depending on the frequency of exercise. Significant decrease in SOD, CAT, and GPx activity ($P < 0.05$) at the frequency of physical exercise 4 and 7 times a week compared to the control group and experimental group 1. However, there was no significant difference between the exercise frequency 2 times a week with the control group. The decrease in SOD activity after exercise with more frequency was due to the use of sufficient amounts of SOD to prevent an increase in free radical production. Although this reaction is spontaneous and fast, the reaction SOD catalyzes is four times faster [35]. There are three different mechanisms for reducing H_2O_2. First, it is a substrate for two enzymes, catalase and glutathione peroxidase (GPx), catalyzing the conversion of H_2O_2 to $H_2O + O_2$ [36].

Second, myeloperoxidase (MPO) converts H2O2 to hypochlorous acid (HOCl) in neutrophils. HOCl is a strong oxidant that acts as a bactericidal agent in phagocytic cells, a physiological toxic agent mechanism. When HOCl reacts with H_2O_2, singlet oxygen ($1O_2$) and water are produced. Third, H2O2 is converted into hydroxyl radicals. Third, H_2O_2 is converted into hydroxyl radicals. The existence of oxidative stress caused by physical exercise with a frequency quite often in one week and lack of recovery time causes muscle protein breakdown and protein degradation. This causes a decrease in muscle mass. As a result, the levels of antioxidants in the body also decrease, namely the levels of SOD, CAT, and GPx, because there is no more intake to neutralize ROS.

In the results of this study, when viewed from the levels of lactic acid dehydrogenase (LDH). After physical exercise with a frequency of 2 times a week, LDH levels increased compared to the control group who were not given physical exercise, although the increase was not significant. Meanwhile, the group of rats that were given physical exercise with a frequency of 4 times a week and 7 times a week had a significant difference. This significant increase in LDH levels indicates that there is damage to the muscle tissue. Increased LDH levels occur due to increased volume and intensity of training, which causes changes in immunology and hormones [37]. Some research also found that high-intensity continuous exercise and limited recovery time can cause an increase in enzyme activity related to glucose metabolism, namely LDH [38].

The accumulation of large amounts of LDH in the blood and muscles can cause muscle fatigue. The occurrence of the formation of lactic acid due to insufficient oxygen supply from blood circulation. The emergence of fatigue due to increased levels of lactic acid will cause the pH to decrease so that the formation of ATP is inhibited. However, lactic acid can still be converted to glucose.

LDH activity in the blood is very low at rest, but if there is damage to the muscle cells damaged by high-intensity exercise, then the LDH in the cells is released out of the cells, and LDH activity in the blood increases [39]. LDH in muscle catalyzes the reduction of pyruvate to lactate, which occurs at a higher rate when glycolysis is increased, such as during muscle contraction [40]. LDH is a blood-specific enzyme that can be used to evaluate the energy system in various types of exercise. It represents the degree of adaptation of metabolic functions during energy metabolism, exercise intensity, muscle stiffness, fatigue, and overtraining [41].

Oxidative stress can damage cells, triggering an inflammatory response characterized by the release of pro-inflammatory mediators such as cytokines (TNF-α, IL-1, and IL-6) by macrophages during heavy-intensity exercise and limited recovery time [42]. In the study, the pro-inflammatory mediators measured were interleukin-6. This study proves that providing physical exercise with less recovery time can increase interleukin-6 levels significantly ($p < 0.05$). Increased oxidative stress due to limited recovery time after physical exercise can damage cells, allowing intracellular molecules such as enzymes to move to the extracellular space [43]. An increase in the enzyme creatine kinase indicates muscle cell damage. Abnormally high levels of enzymes in serum or plasma can be a sign of damage to the cells that contain these enzymes [44]. This study also proves that physical exercise with limited recovery time can significantly increase muscle cell damage, as indicated by high levels of creatine phosphokinase.

Conclusion

Based on this study, physical exercise must be accompanied by sufficient recovery time to avoid decreased serum antioxidant levels and increased muscle tissue damage.

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