

ABSTRAK

Penuaan seluler ditandai dengan peningkatan stres oksidatif yang dimanifestasikan melalui peningkatan malondialdehid (MDA) dan penurunan superoksida dismutase (SOD). Latihan fisik telah terbukti memiliki efek protektif terhadap penuaan, namun hubungan *dose-response* antara intensitas latihan dengan biomarker stres oksidatif pada model penuaan belum sepenuhnya terkarakterisasi. Studi ini bertujuan untuk mengevaluasi efek latihan fisik kombinasi treadmill dan berenang dengan variasi intensitas terhadap kadar serum MDA dan SOD pada tikus putih galur Wistar model penuaan induksi D-galaktosa. Penelitian eksperimental dengan desain *randomized post-test only with control group* menggunakan 28 ekor tikus Wistar jantan (160-200 gram, usia 2-3 bulan) yang diinduksi penuaan dengan D-galaktosa 300 mg/kg/hari intraperitoneal selama 7 hari. Subjek dibagi menjadi 4 kelompok (n=7): K0 (kontrol tanpa latihan), K1 (*treadmill* 10 m/menit dan berenang), K2 (*treadmill* 20 m/menit dan berenang), dan K3 (*treadmill* 30 m/menit dan berenang), masing-masing selama 30 menit, 5 kali per minggu, 2 minggu, dikombinasikan dengan latihan berenang 60 menit, 5 kali per minggu, 4 minggu. Kadar serum MDA dan SOD diukur menggunakan ELISA. Analisis data menggunakan ANOVA satu arah dan uji post hoc Tukey HSD ($\alpha=0,05$). Hasil penelitian menunjukkan terdapat perbedaan bermakna kadar MDA antar kelompok ($F=98,53$; $p<0,001$). Rerata kadar MDA menurun seiring peningkatan intensitas, K0 ($8,19\pm0,47$ nmol/mL), K1 ($6,54\pm0,62$ nmol/mL), K2 ($4,95\pm0,51$ nmol/mL), dan K3 ($3,75\pm0,41$ nmol/mL). Kadar SOD meningkat signifikan antar kelompok ($F=217,23$; $p<0,001$) dengan pola dose-response: K0 ($24,93\pm2,59$ U/mL), K1 ($32,42\pm1,79$ U/mL), K2 ($42,95\pm1,97$ U/mL), dan K3 ($50,98\pm1,76$ U/mL). Semua perbandingan antar kelompok menunjukkan perbedaan bermakna ($p<0,05$). Latihan fisik kombinasi *treadmill* dan berenang memiliki aktivitas anti-aging melalui modulasi stres oksidatif dengan menurunkan MDA dan meningkatkan SOD secara *dose-dependent*. Intensitas latihan yang lebih tinggi (30 m/menit) memberikan efek protektif optimal terhadap penuaan seluler pada model tikus.

Kata Kunci: Latihan Fisik, *Treadmill*, Malondialdehid, Superoksida Dismutase, Stres Oksidatif

ABSTRACT

Cellular aging is characterized by increased oxidative stress manifested through increased malondialdehyde (MDA) and decreased superoxide dismutase (SOD). Physical exercise has been shown to have a protective effect against aging, but the dose-response relationship between exercise intensity and oxidative stress biomarkers in aging models has not been fully characterized. This study aimed to evaluate the effects of a combination of treadmill and swimming exercise with varying intensity on serum MDA and SOD levels in Wistar rats as a D-galactose-induced aging model. This experimental study with a randomized post-test only design with a control group used 28 male Wistar rats (160-200 grams, 2-3 months old) induced by aging with 300 mg/kg/day intraperitoneal D-galactose for 7 days. Subjects were divided into 4 groups (n=7): K0 (control without exercise), K1 (treadmill 10 m/min and swimming), K2 (treadmill 20 m/min and swimming), and K3 (treadmill 30 m/min and swimming), each for 30 minutes, 5 times per week, 2 weeks, combined with swimming exercise 60 minutes, 5 times per week, 4 weeks. Serum MDA and SOD levels were measured using ELISA. Data analysis used one-way ANOVA and Tukey HSD post hoc test ($\alpha=0.05$). The results showed a significant difference in MDA levels between groups ($F=98.53$; $p<0.001$). Mean MDA levels decreased with increasing intensity, K0 (8.19 ± 0.47 nmol/mL), K1 (6.54 ± 0.62 nmol/mL), K2 (4.95 ± 0.51 nmol/mL), and K3 (3.75 ± 0.41 nmol/mL). SOD levels increased significantly between groups ($F=217.23$; $p<0.001$) with a dose-response pattern: K0 (24.93 ± 2.59 U/mL), K1 (32.42 ± 1.79 U/mL), K2 (42.95 ± 1.97 U/mL), and K3 (50.98 ± 1.76 U/mL). All comparisons between groups showed significant differences ($p<0.05$). The combination of treadmill and swimming exercise has anti-aging activity through modulation of oxidative stress by decreasing MDA and increasing SOD in a dose-dependent manner. Higher exercise intensity (30 m/min) provided optimal protective effects against cellular aging in a mouse model.

Keywords: *Physical Exercise, Treadmill, Malondialdehyde, Superoxide Dismutase, Oxidative Stress*