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Effects of different endurance training intensities on resting levels of skeletal muscle and liver glycogen concentrations in male rats

Abbass Ghanbari-Niaki [1*], Zahra Farshidi [2], Rozita Fathi [1]

[1] Department of Physical Education and Sports Science, Baboulsar University, Baboulsar, IR Iran
[2] Department of Physical Education and Sports Science, Neyriz Branch, Islamic Azad University , Neyriz, IR Iran

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ABSTRACT

Background: Liver and muscle glycogen are main energy sources, that playcrucial rolesin muscular functionand maintenance of blood glucose levels during short and vigorous exercise. Much data is available on the effects of different types of physical exercise training on liver and muscle glycogen contents, showing that endurance-trained humans and animals have higher liver and muscle glycogen contents, when compared with sedentary counterparts.
Objectives: The purpose of current study was to investigate the effects of treadmill running at different intensities on the glycogen contents of liver and skeletal muscle.
Materials and Methods: Forty male wistar rats (14-16weeks old, weighing 250-260 g) were randomly assigned tocontrols (No. = 10), and the low (18 m/min)(No. = 10), moderate (26 m/min)(No. = 8)and high (34 m/min)(No. = 10) intensity groups.The three training groups ran for 60 min/d, 5d/wk at 18, 26, and 34 m/min and 0% grade for 12 weeks.Forty-eight hours after the last exercise session, rats were sacri, and liver and gastrocnemius muscle were collected and frozen in liquid nitrogen for glycogen measurements. One way ANVOA was, used and significance level was set at $P \leq 0.05$.
Results: Data demonstrated that the trained groups had higher liver and lower muscle glycogen contents when compared to the control group, with the moderate exercise group having the highest levels.
Conclusions: Moderate intensity exercise seems more suitable for maintaining and improving glycogen levels in liver and muscle.

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Background

Liver and muscle glycogen play an important role in maintenance of both muscular function blood glucose levels within normal values (1). The effects of different types of physical exercise (acute/chronic) and training on liver and muscle glycogen contents have been well documented (2-4). It is also been suggested that liver and muscle glycogenolysis ratesincrease more during high than during low exercise intensities at specific times, which, in turn, has an impact on the rate of post-exercise glycogen resynthesis and its contents in liver and worked muscles during the recovery period (5-10). Robergs *et al.* (5) investigated effects of weight-resistance exercise on muscle glycogen degradation, and reported that a greater rate of muscle glycogenolysis occurred in the 70% 1RM, compared to the 35% 1RM, and consequently there was a 20–40% reduction in muscle glycogen after intensive exercise. Previous studies have focused mostly on the temporary effect of high intensity exercise on muscle glycogen content, and not enough on the effect of exercise training programs at different intensities on resting liver and muscle glycogen, simultaneously (11). Recently, Fathi *et al.* (10) studied the effect of different intensities on plasma and tissue acyl ghrelin and soleus

* *Corresponding author at:* Abbass Ghanbari-Niaki, Department of Physical Education and Sports Science, Baboulsar University, Baboulsar, IR Iran. Fax: +981125342202.
E-mail: aghanbariniaki@gmail.com

muscle (slow-twitch, oxidative fibers) glycogen content, butthey did not focus on liver and gastrocnemius muscle (fast-twitch, glycolytic) glycogen contents.

Objectives

The first aim of this study was to investigate the effect of treadmill running programs at different intensities (18, 26, and 34 m/min for 12 weeks) on the glycogen content of liver and gatrocnemius muscle as two metabolic tissues, and the second aim was to ascertain which intensity is more effective on the levels of glycogen in these tissues.

Materials and Methods

Animals

Forty male Wistar rats (14-16weeks old, weighing 250-260 g) were considered for this study. Animals were obtained from Razi's Institute (Tehran, Iran) and maintained in the Central Animal House, School of Medical Sciences of Tarbiat Modares University (TMU), and were housed five per cage, with the light controlled in 12:12 hour light–dark cycle; room temperature wasadjusted to 22 ± 1.4 °C and relative humidity was 55.6 ± 4.0%. Animals were fed standard rodent chow (67.5% carbohydrate, 11.7% fat, 20.8% protein, Khorak-Dame Pars, Tehran, Iran), given ad libitum access to water, and familiarized with laboratory conditions for 1 wk before experimentation.

Exercise training protocol

Animals were randomly assigned into four training groups of ten animals each: Control, low (18 m/min), moderate (26 m/min) and high (34 m/min) intensities. The control group remained sedentary while the training groups underwent motor-driven treadmill running (at 18, 26, and 34m/min, 60min/day, 5 days/week, for 12 weeks). Treadmill training began with familiarization of rats with the apparatus for 7 days, when theybecame progressively accustomed to running on a motor-driven rodent treadmill, beginning with 10-15 min/day at 10 m/min, and increased to 60 min/day at the three intensities mentioned (0% grade).

Tissue biopsy and biochemical measurements

All rats were fasted overnight and thirty-six hours after the last session of training (12th week) were anesthetized intra- peritoneally with a mixture of Ketamine (30–50 mg/kg bw, ip) and Xylazine (3–5 mg/kg bw, ip).Parts of the liver and skeletal muscle (Gastrocnemius) were removed, cleaned and immediately frozen in liquid nitrogen, all frozen tissue pieces being stored at -80 °C, until measurements were performed. Tissue samples were homogenized in five volumes of buffer containing 0.9% NaCl, 50 mM Tris-Hcl, 12 μM leupeptin, using a Potter-Elvejheim homogenizer set at 800 rpm and cooled in ice. Glycogen content was obtained using the Glycogen Colorimetric kit (Nanjing Jiancheng Bioengineering Institute, Nanjing, China).

Statistical analysis

All results are expressed as Means ± standard error (SEM). Data were analyzed by the one-way ANOVA method, statistical significance being set at $P \leq 0.05$. All statistical analysis was performed by using SPSS software (Version 15).

Results

The descriptive characteristics of the subjects are presented in *table 1.* Resting liver glycogen levels were significantly higher in trained animals, compared to the control group. A higher glycogen level was also found in the moderate exercise intensity group when compared with other groups *(Figure 1)*. Changes in resting gastreocnemius muscle glycogen concentrations were significant. Data revealed that the glycogen content was significantly lower in the high intensity group compared to the low-intensity groups and controls *(Figure 1)*.

Discussion

The main finding of the current study was a higher liver glycogen concentration in the moderate-intensity group and lower muscle glycogen concentrations in the high-intensity group, indicating that liver and muscle glycogen respond differently to exercise in rats fasted overnight. Higher liver and muscle glycogen contents have been reported in trained human and animal sub-

Table 1. Physical characteristics of subjects as Means ± SEM

Group	No.	Weight (g)	Height (cm)
Control	10	345.0 ± 12.6	23.7 ± 0.2
Low Intensity	10	326.4 ± 12.6	23.6 ± 0.2
Moderate Intensity	8	321.5 ± 8.2	23.4 ± 0.2
High Intensity	10	320.0 ± 11.5	23.2 ± 0.4

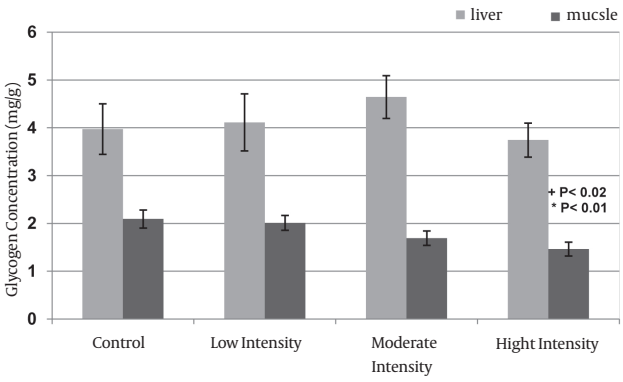

Figure 1. Glycogen concentrations in the liver vs. skeletal muscle in four groups, values are Mean ± SEM. + Significant difference with low intensity group, * Significant difference with control group

jects by several investigators (8-14). Data regarding liver glycogen are in agreement with previously reported results 12-14, but are in disagreement with others (10, 15, 16). Lower gastrocnemius and soleus muscle glycogen levels following acute high-intensity exercise and training have also been reported by several researchers (10-12, 16, 17). Although the mechan-isms by which treadmill exercise training alters liver and muscle glycogen contents have been investigated and documented, they still need to be clarified. In this study we did not discuss the variables implicated in glycogen metabolism and disposal, but it is well documented that exercise training results in sparing muscle and liver glycogen during exercise, post-exercise / training liver glycogen supercompensation (glycogen overshoot or higher glycogen content than normal condition) period, and increases glucose transporter gene expressionin different tissues (17-19). Lower gastrocnemius muscle glycogen might be attributed to the several possible factors such as nutritional status (fasting vs. fed) 10, exercise-induced muscle damage11, and incomplete glycogen restoration because of recovery time following exercise (20). In conclusion these results indicate that liver and gastrocnemius muscle respond to exercise training differently under short term fasting state (overnight fasting), which might be related to the weight and glycogen storage in both liver and gastrocnemius muscle tissues. It seems that training programs at low to moderate exercise intensities (18m/min and 26m/min) are suitable for the improvement and maintenance of the muscle and liver glycogen contents. Further investigation of the effects of low and moderate exercise intensity on the related elements of tissue glycogen improvement is recommended to confirm these findings.

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Conflict of interest

None declared.

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