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Full Length Research Paper

Gastrodia elata Blume extract ameliorates exercise-induced fatigue

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To investigate the effect of *Gastrodia elata* Blume (GEB) extract on exercise-induced fatigue recovery, 120 mice were divided at random into four experimental groups (3 GEB administered groups and the normal control group). The normal control group were gavaged with distilled water and the GEB administered groups were gavaged with GEB extract (1000, 500 and 200 mg/kg) for seven consecutive days. The effect of GEB extract on the performance of forced swimming time and blood biochemical parameters related to fatigue blood urea nitrogen (BUN) and blood lactate were measured after forced swimming test (FST). The results indicated that the administration of GEB extract could elevate the endurance of the mice, lower the blood lactate produced and prevent the increase of serum BUN of mice after swimming. GEB extract ameliorates exercise-induced fatigue.

Key words: *Gastrodia elata* Blume, exercise, fatigue.

INTRODUCTION

Fatigue is a complex phenomenon that can be described as a time-dependent exercise-induced reduction in the maximal force generating capacity of a muscle (Gandevia, 2001). Alteration in performance tends to vary across sports that are influenced more or less by factors like decreased muscular power and endurance, decreased motor skill performance and mental lapses (Letafatkar et al., 2009). Since the available therapies for fatigue in modern medicine are very limited, potential alternatives from traditional medicine and their respective mechanisms of action is worth investigating (Tharakan et al., 2005). Traditional Chinese medicine (TCM) has been reported to be useful and with little side-effects for fatigue not only in China but also in other parts of the world (Zhao, 2005; Mears, 2005). In traditional Chinese medicine, it is believed that exercise-induced fatigue is related to the depletion of energy materials in the body. It is also related to the disorder of nervous, endocrine and immunity systems.

Gastrodia elata Blume (GEB) (Tianma in Chinese) is a traditional herbal plant. The rhizomes of GEB have been used in traditional Chinese medicine for the treatment of headaches, dizziness, vertigo and convulsive illnesses, such as epilepsy and tetanus (Huang et al., 2007). The major components present in *G. elata* Blume are gastrodin (GA), vanillyl alcohol (VA), and 4-hydroxybenzaldyde (HBA) and the molecular structures are shown in Figure 1 (Ong et al., 2007). Recent studies have shown that GEB gives anticonvulsive (Hsieh et al., 2001), antioxidative and free radical scavenging (Liu and Mori, 1992, Ha et al., 2000), learning improvement (Wu et al., 1996), memory consolidation and retrieval (Hsieh et al., 1997) and anti-fungal effects (Xu et al., 1998; Wang et al., 2001). The anti-fatigue effect of GEB has not been previously demonstrated. The aim of this study is to investigate the effects of *G. elata* Blume extract on exercise-induced fatigue recovery.

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Abbreviations: GEB, *Gastrodia elata* Blume; **BUN,** blood urea nitrogen; **FST,** forced swimming test; **TCM,** traditional Chinese medicine ; **GA,** gastrodin; **VA,** vanillyl alcohol; **HBA,** 4-hydroxybenzaldyde; **NC,** normal control group; **HGA,** high-dose *Gastrodia elata* Blume administered group; **MGA,** middle-dose *Gastrodia elata* Blume administered group; **LGA,** low-dose *Gastrodia elata* Blume administered group.

MATERIALS AND METHODS

Plant material

Dried rhizomes of GEB were purchased from a local herbal store in Dezhou. The specimen was identified by comparison with voucher

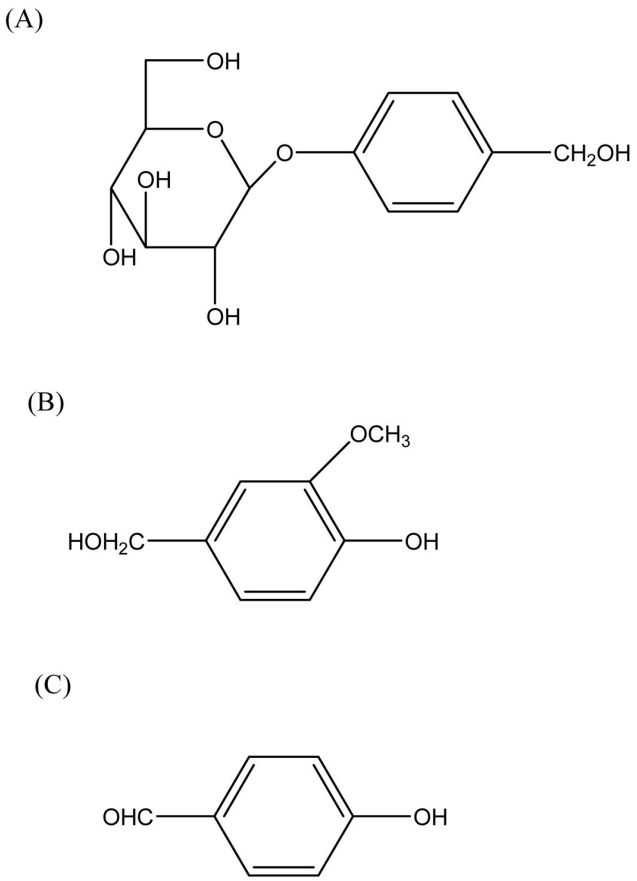

Figure 1. Chemical structures of (A) GA, (B) VA and (C) 4-HBA.

specimens deposited earlier at the Herbarium of Dezhou University.

Preparation of the GEB extract

The washed and chopped fresh GEB was deep-frozen at -70℃ until freeze-dried to get power. GEB was extracted with methanol and the methanol extract was re-suspended in 30% methanol. After centrifugation, the supernatants were dried in a rotary evaporator. The color of the fraction was dark brown (An et al., 2007).

Animals

Male Kunming mice (18 - 22 g, Grade II, certificate No SCXK (Lu) 2008-0003 experimental Animal enter of Dezhou University, China) were group housed in a regulated environment (23 ± 2℃), with a 12-h light and 12-h dark cycle (08:00 - 20:00, light). Food and water were given *ad libitum*, except during behavioral experiments. Mice were adapted to diet for 1 week before the experiment began. 120 mice were divided at random into four experimental groups, with 30 mice per group. The mice were divided into the following groups: Normal control group (NC), mice were gavaged with 5 ml distilled water for 7 consecutive days; high-dose GEB administered group (HGA), mice were gavaged with GEB extract (1000 mg/kg) for 7 consecutive days; middle-dose GEB administered group (MGA), mice were gavaged with GEB extract (500 mg/kg) for 7 consecutive days; low-dose GEB administered group (LGA), mice were gavaged with GEB extract (200 mg/kg) for 7 consecutive days.

The GEB extract administered for each group were dissolved in distilled water at the designated concentration, and each 5 ml of the distilled water was then fed to the mouse by gavage every day. The study was conducted in accordance with Good Laboratory Practice (GLP) Regulations of the World Health Organisation (WHO).

Forced swimming test (FST)

FST was used as described previously with some modifications (Moriura et al., 1996; Liu et al., 2004; Wu et al., 2007). The test was induced by forcing animals to swim until exhaustion. Ten mice were taken out from each group to make swimming test after being administrated with different doses of GEB extract for 7 days. The mice were loaded with lead rings that weighed 5% of their body weight to the tail, and were then placed in the swimming tank filled with fresh water (approximately 30 cm deep water). Water temperature was maintained at 30 ± 1℃. Exhaustion was determined by observing loss of coordinated movements and failure to return to the surface within 8 s (Matsumoto et al., 1996; Liu et al., 2004). This 8 s criterion was considered to correlate with exhaustion, and was used as an indication of the maximum swimming capacity of the animal. Mice were removed at this point, before drowning. The swimming time was measured.

Determination of biochemical parameters

Ten mice were taken out from each group for blood lactate analyses after being administrated with different doses of GEB extract for 7 days. The mice were loaded with lead rings that weighed 2% of their body weight to the tail, and were then placed in the swimming tank filled with fresh water. After the mice swam freely for 60 min, 20 ul blood was collected by removing the eyeball from the socket under general anesthesia with a pair of tissue forceps. Then blood lactate was determined by using an assay kit (Nanjing Jiancheng Bioengineering Institute, Nanjing, China) according to the manufacturer's protocol.

Ten mice were taken out from each group for blood urea nitrogen (BUN) after being administrated with different doses of GEB extract for 7 days. After the mice might have swam freely for 90 min without any load, 500 ul blood was collected by removing the eyeball from the socket under general anesthesia with a pair of tissue forceps. Blood serum was prepared by centrifugation at 800 xg at 4℃ for 10 min. Then, levels of serum BUN was determined using an assay kit (Nanjing Jiancheng Bioengineering Institute, Nanjing, China) according to the manufacturer's protocol.

Statistical analysis

Data were assessed by using the statistical package for the social sciences (SPSS) program (version15.0, SPSS Inc., Chicago, IL, USA). $p<0.05$ between mean values were considered statistically significant.

RESULTS AND DISCUSSION

Weight-loaded forced swimming test

The forced swimming test which is perhaps one of the most commonly used animal models of behavioral despair, has been used extensively for the evaluation of anti-fatigue property of a novel compound and was also used

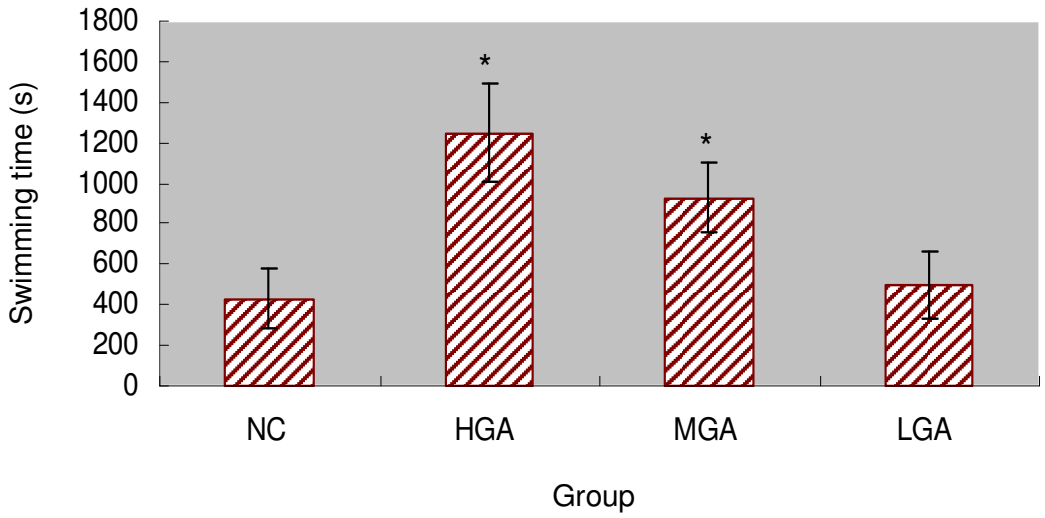

Figure 2. Swimming time to exhaustion in forced swimming tests. Values are the means ± SD. (n = 10, respectively). *P < 0.05 indicates significant difference from the control group.

as an endurance test (Ikeuchi et al., 2006; Zhang et al., 2006; Tang et al., 2009). The mice loaded with 5% of their body weight were placed in water at room temperature (30 ± 1°C) to swim. As shown in Figure 2, the swimming time to exhaustion of the control group and GEB administered groups was 429.34 ± 150.71, 1249.15 ± 238.56, 926.61 ± 172.28 and 598.39 ± 163.64 s, respectively. There were no differences in the time to exhaustion between the NC group and LGA group ($p>0.05$). The swimming time to exhaustion of the HGA group and MGA group were significantly longer than that of the control group ($p<0.05$). These results showed that mice administrated with different doses of GEB extract (1000 and 500 mg/kg) swam for a significantly longer time until exhaustion. It indicated that GEB extract could elevate the endurance of the mice.

Effects of GEB extract on blood lactate

Continuous exercise causes fatigue, which can be inhibited by the administration of nutritional regimens, suppressing fatigue relevance factors (Keuchi et al., 2005). Lactate is a key indicator of fatigue. Many organs, especially the liver, heart and skeletal muscle help remove lactate from the blood (Bonen, 2000; Brook, 2000) but intense exercise can increase lactate production to a point that exceeds the rate of lactate removal, which results in fatigue. Furthermore, the increase of lactate level will bring about a reduction of pH in muscle tissue and blood, and also induce many side effects of various biochemical and physiological processes. Therefore, rapid removal of lactate is beneficial to relieving fatigue (Tang et al., 2008). The level of blood lactate of control and GEB administered groups are clearly depicted in Figure 3. After the mice might have swam freely for 60 min, the level of blood lactate of the control group and GEB administered groups was 64.37 ± 9.16, 46.93 ± 8.81, 51.62 ± 9.53 and 53.39 ± 9.87 mmol/l, respectively. The level of blood lactate of GEB administered groups was significantly lower than that of the control group ($p<0.05$). These results indicated that GEB extract could effectively lower the blood lactate of the mice produced after swimming, postpone the appearance of fatigue and accelerate the recovery from fatigue.

Effects of GEB extract on BUN

BUN, the product of energy metabolism when moving, is a sensitive index to evaluating the bearing capability when body suffers from a physical load. There is a positive correlation between the urea nitrogen *in vivo* and the exercise tolerance. In other words, the more the body is adapted to exercise tolerance, the more significantly the urea nitrogen level increases (Tsopanakis and Tsopanakis, 1998; Tang et al., 2008). As shown in Figure 4, after the mice swam freely for 90 min without any load, the content of serum BUN of the control group and GEB administered groups was 7.91 ± 0.98, 5.21 ± 1.03, 5.68 ± 1.07 and 7.38 ± 1.26 mmol/l, respectively. There were no differences in the content of serum BUN between the NC group and LGA group ($p>0.05$). The content of serum BUN of the HGA and MGA group were significantly lower than that of the control group ($p<0.05$). These results indicated that GEB extract could prevent the increase of serum BUN of mice after swimming.

Conclusion

In conclusion, our data suggested that *G. elata* Blume

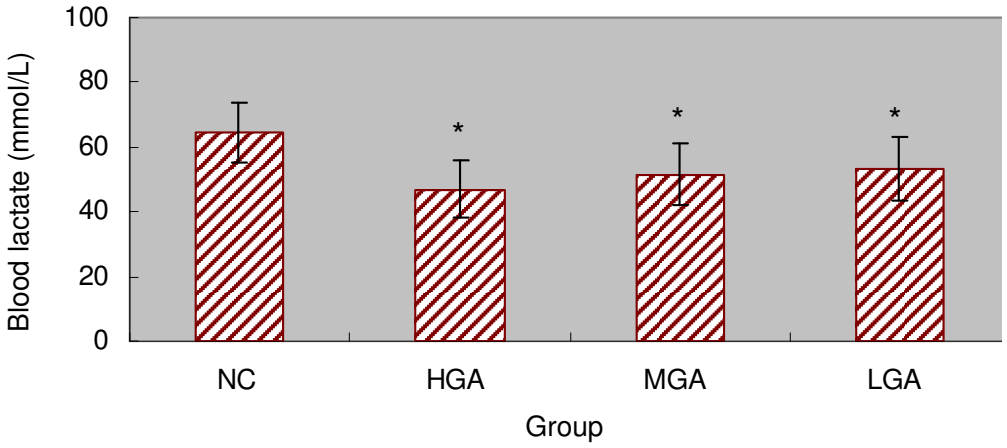

Figure 3. Effects of GEB extract on blood lactate. Values are the means ± SD. (n = 10, respectively). *P < 0.05 indicates significant difference from the control group.

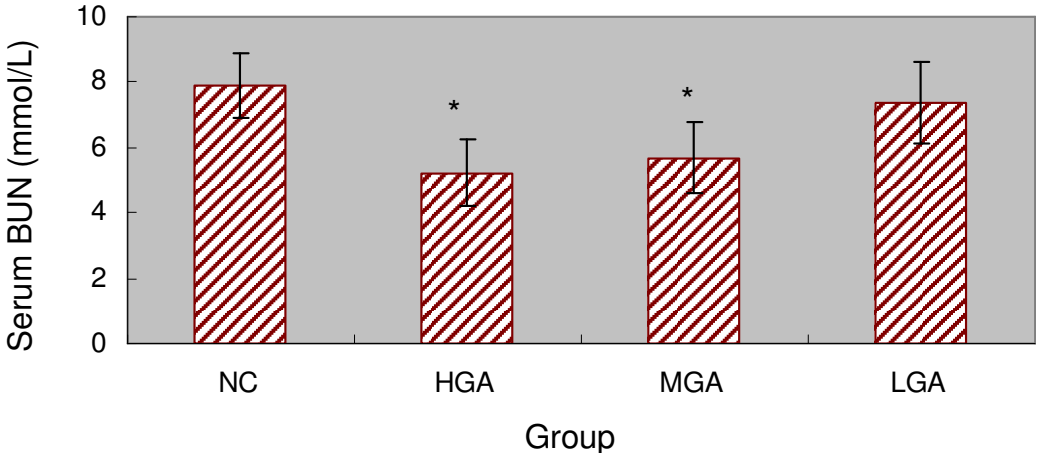

Figure 4. Effects of GEB extract on BUN. Values are the means ± S.D. (n = 10, respectively). *P < 0.05 indicates significant difference from the control group.

extract ameliorated exercise-induced fatigue. The administration of GEB extract could elevate the endurance of the mice, lower the blood lactate produced and prevent the increase of serum BUN of mice after swimming. The anti-fatigue effect of GEB extract seemed to be a comprehensive effect of its various constituents. To clarify the mechanism underlying the anti-fatigue effect and active component of GEB extract, further studies are warranted by using new adequate animal models.

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