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Effects of Standardized Ginseng Extract and Exercise Training on Aerobic and Anaerobic Exercise Capacities in Humans

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Abstract□This study was undertaken to determine whether administration of a standardized ginseng extract at 300 mg·d^{-1} for 8 weeks could enhance maximum aerobic and anaerobic exercise capabilities and whether any changes of such effects can be occurred when exercise training was added. Forty-one male university students were randomly divided into four groups as ginseng-untrained (GU, n=10), ginseng-trained (GT, n=10), placebo-untrained (PU, n=10), and placebo-trained (PT, n=11). The trained groups underwent 8 weeks of aerobic exercise at 65% of individual's maximum oxygen consumption ($\dot{V}_{O_2}$ max) for 30 min·d^{-1}, 3d·wk^{-1}. Prior to and at the end of experiment, $\dot{V}_{O_2}$ max, anaerobic power (AP), anaerobic capacity (AC), and leg muscle strength were determined and some physiological parameters related to $\dot{V}_{O_2}$ max were measured. Initially, all subject groups did not differ in average $\dot{V}_{O_2}$ max (range 45.9 to 47.9 ml·kg^{-1}·min^{-1}). After 8 weeks, the $\dot{V}_{O_2}$ max increased significantly from the initial level by 12.6% in group GU, 14.5% in group PT, and 24.5% in group GT which was significantly higher than group GU but not group PT. Changes in all measured parameters related to $\dot{V}_{O_2}$ max were similar among the subject groups except group PU. Both the AP and the AC were significantly increased in all subject groups (range +3.6 to +13.1% above initial for the AP and +4.4 to +8.9% above initial for the AC) but the higher changes were found for the AP in groups PT and GU, and for the AC in group PT, when compared with group PU. No significant differences in the two anaerobic variables were observed between group GT and the other groups of subjects. Leg strength was also significantly enhanced over group PU in groups PT, GU and GT. There were no significant differences among the latter three subject groups. As a result of these findings, it was concluded that under the conditions of this study ginseng administration at the prescribed dose exhibited the training-like effects on $\dot{V}_{O_2}$ max as well as anaerobic power and leg muscle strength but no clear synergistic action on these physical fitness variables occurred when both ginseng administration and exercise training were combined.

Key words□standardized ginseng extract, exercise training, $\dot{V}_{O_2}$ max, anaerobic power, anaerobic capacity, leg muscle strength.

Introduction

Ginseng has been known among Asian peoples for thousands of years as a panacea against illness. During the last few decades, the primary active ingredients of ginseng have been extracted and prepared for commercial purpose.[1] The ginseng preparation containing a quantitatively and qualitatively standardized ginseng extract has been tested in both animals and humans and shown to possess various beneficial physiological effects as well as favorable outcome on physical and mental performance such as a better learning and memory and an increased locomotor activity in rats,[2], an improved pulmonary function in middle aged men and women,[3] and improvements in recovery phase of submaximal exercise test, reaction time, hand coordination, concentration, and memory in young and old humans.[4] However, most of the reports on the

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effects of the standardized ginseng extract on physical performance in humans confined to untrained condition. Although it is known that endurance exercise training could markedly enhance maximal rate of oxygen consumption ($\dot{V}_{O_2}$ max) especially in low fit non-athletes when compared with the fit endurance athletes,[5,6] it remains unknown whether such effect of exercise training could be efficiently enhanced if it was superimposed by administration of the ginseng extract. Accordingly, the present study was conducted to determine the combined effects of the ginseng extract and exercise training on aerobic exercise capacity in a single experiment and to compare them with the effects of separated individual treatments in healthy young non-athletic males. In addition, since the role of the ginseng extract on anaerobic exercise capacity remains undetermined, the maximum anaerobic power and anaerobic capacity of the subjects were also tested.

Materials and Methods

1. Subjects

Forty-one healthy male university students, aged 19~26 yrs, volunteered to participate in the present study. Following a medical examination each subject was informed the purpose of the study and the associated risks and gave informed consent to the experimental protocol approved by the Mahidol University Human Subjects Ethical Review Committee. All subjects were physicaly active, took no medication at the time of the study, had neither serious past illnesses nor previous exercise training.

The subjects were randomly divided into four groups. Group 1 (GU) received standardized ginseng extract and was not trained (n=10). Group 2 (GT) received both ginseng and training (n=10). Group 3 (PU) received a placebo and was not trained (n=10). Group 4 (PT) received a placebo and was trained (n=11). There were no significant differences among the four groups with regard to physical characteristics and initial aerobic fitness level.

2. Study design

A double blind study was conducted in the present experiment which lasted for 8 weeks. The dose of the standardized ginseng extract, 150 mg per capsule (Pharmagin, New Century Pharma, Seoul, Korea) was fixed at 2 capsules daily (one in the morning and one at midday). The placebo capsule containing a pharmacological neutral content was served as control. The ginseng extract and the placebo preparations were identical in appearance, weight, and size. The packs of each drug were marked with a code designed for the study, neither the tested subjects nor the persons responsible for giving the drugs to the subjects were familiar with the code.

During the 8 wk period of drug administraion, the subjects assigned to the training groups performed aerobic exercise training with bicycle ergometer (Bodyguard 990, Sandners, Norway) at an intensity of 65% $\dot{V}_{O_2}$ max for 30 min·d^{-1}, 3d·wk^{-1}. Training was conducted in the afternoon in an open non-airconditioned laboratory room. Ambient temperature and relative humidity at the time of training were 29~31℃ and 71~75%, respectively. Subjects in the untrained groups were instructed to maintain their usual activity pattern.

Prior to and at the end of the 8 wk experimental period, the subjects' physiological and physical fitness characteristics were determined. For subjects of the exercise training groups, these determinations were conducted on a day of no training. All measurements were performed in an air-conditioned laboratory at temperature of 22~25℃ and relative humidity of 50~55%.

3. Measurements

Maximum oxygen consumption ($\dot{V}_{O_2}$ max) was measured during a progressive exercise on a cycle ergometer (Monark 818, Sweden). After a period of resting on the ergometer, the subjects first cycled at O W at 60 rpm for 4 min of warming up, after which the power was increased by 30 W every 2 min until exhaustion. Throughout the test, oxygen consumption ($\dot{V}_{O_2}$) and carbon dioxide production ($\dot{V}_{CO_2}$) were determined by the open-circuit method using expiratory air data. Expiratory gases were analyzed for O_2 by O_2 analyzer (Beckman OM-11) and for CO_2 by an infrared CO_2 analyzer (Beckman LB-2) after calibration with gases of known concentration. Expiratory airflow was measured via a pneumotachograph (Fliesch No. 2) and a differential pressure transducer (Grass PT 5). The electrical output from these devices were recorded on a multichannel chart recorder (Grass Model 7) and the values were transferred to a microcomputer for calculations of minute ventilation ($\dot{V}_E$), $\dot{V}_{O_2}$, and $\dot{V}_{CO_2}$ at a standard air condition after correction for ambient temperature and pressure. Respiratory exchange ratio (RER; $\dot{V}_{CO_2}/\dot{V}_{O_2}$) and ventilatory equivalent for O_2 ($\dot{V}_E/\dot{V}_{O_2}$) were also calculated. $\dot{V}_{O_2}$ max was determined as the peak of $\dot{V}_{O_2}$ during the final stages of exercise, provided that the RER was at least 1.10. At rest and during exercise, heart rate was continuously monitored using heart rate measuring device (Sport tester PE-3000, Finland). Resting arterial blood pressure was measured by indirect auscultatory method using stethoscope and sphygmomanometer (A11-K2, Japan).

Anaerobic power and anaerobic capacity were evaluated on the bases of the Wingate test[7] by pedalling against a load as rapidly as possible for 30 sec on a bicycle ergometer (Monark 818, Sweden). The load was set at 67 $g \cdot kg^{-1}$ of the subject's body weight. The subject must pedal at top speed and the number of revolutions of pedalling was recorded every 5 sec. The maximal 5-sec mechanical power and the total power in 30 sec, expressed in $W \cdot kg^{-1}$ body weight, were determined and designated as anaerobic power and anaerobic capacity, respectively.

Isometric leg strength was measured with a calibrated dynamometer (Takei kiki, Japan) as previously described.[8] Each subject performed a maximum contraction force while standing with a fixed knee (135°). The test was measured three times and the best value was recorded.

Percent body fat was indirectly determined by measuring skinfold thickness with the use of a skinfold caliper (Lange, Cambridge Scientific Industries) as described by Durnin and Rahaman,[9] and by calculation according to the equation of Siri.[10]

4. Statistics

All data are expressed as means± SEM. Statistical evaluation of significant differences was done by using the analysis of variance and the Student t test at the 95% confidence level.

Results

The physical characteristics of the subjects are shown in Table 1. Prior to exercise training and administration of either ginseng or placebo, the mean age, height, and weight of each subject group were within the range of 21~22 yrs, 167~170 cm, and 57~61 kg, respectively. There were no significant differences in these characteristics among the four subject groups. Data on physical fitness characteristics determined by non-ergometric test are shown in Table 1. At the beginning (0 wk) of the experiment, the range of the mean value for individual subject group was 16~17% for percent body fat, 65~71 beats/min for resting heart rate, and 104~109 and 65~70 mmHg for systolic and diastolic arterial blood pressure, respectively. No significant differences were observed among the four groups of subjects for these characteristics.

Table 1. Physical characteristics of four subject groups prior to the experiment

	PU (n=10)	PT (n=11)	GU (n=10)	GT (n=10)
Age(yr)	21.0± 0.2	21.6± 0.5	22.1± 0.5	20.9± 0.3
Height(cm)	168.4± 1.4	166.7± 1.5	168.0± 2.5	169.8± 1.2
Weight(kg)	61.2± 1.3	60.2± 1.5	57.4± 1.8	60.0± 1.5
Body fat(%)	15.9± 1.1	17.0± 0.5	16.3± 0.8	16.7± 0.8
Heart rate ($beats \cdot min^{-1}$)	65.6± 2.1	67.1± 1.5	70.8± 1.9	66.6± 2.3
Arterial blood pressure (mmHg):				
−Systolic	109.0± 1.8	109.1± 2.1	104.0± 2.7	109.0± 1.8
−Diastolic	65.0± 3.1	69.1± 3.1	66.0± 2.2	67.0± 1.5

Values are means± SEM. PU=placebo-untrained, PT=placebo-trained, GU=ginseng-untrained, and GT=ginseng-trained.

Table 2. Maximal aerobic and anaerobic exercise data of four subject groups prior to the experiment

	PU (n=10)	PT (n=11)	GU (n=10)	GT (n=10)
$\dot{V}_{O_2}$ max(ml.kg^{-1}.min^{-1})	46.2± 1.6	47.9± 2.4	45.9± 1.8	46.7± 2.3
Values at $\dot{V}_{O_2}$ max:				
− Heart rate (beats·min^{-1})	173.9± 1.2	175.2± 2.1	171.7± 2.0	177.4± 1.5[c]
− O_2 pulse (ml·beat^{-1})	15.9± 0.3	15.8± 0.9	14.9± 1.0	15.8± 0.6
− V_E (1·min^{-1})	63.3± 2.3	62.7± 2.9	60.5± 3.5	61.5± 3.4
− V_E/V_{O_2} ratio	22.9± 0.9	22.7± 0.7	25.0± 0.9	21.9± 1.0[c]
− RER	1.1± 0.02	1.1± 0.02	1.1± 0.01	1.1± 0.02
Leg strength	3.1± 0.2	3.1± 0.2	2.9± 0.2	2.6± 0.2[ab]
Anaerobic power (Watt·kg^{-1})	9.6± 0.2	9.6± 0.2	8.7± 0.2 [ab]	9.3± 0.1[c]
Anaerobic capacity (Watt·kg^{-1})	8.2± 0.2	8.1± 0.1	7.7± 0.2	8.1± 0.9

Values are means± SEM. See Table 1 for explanation of abbreviations for the subject groups.
[a,b,c]indicate significant differences from PU, PT and GU, respectively (at least $p<0.05$).

Aerobic and anaerobic fitness characteristics of the subjects prior to the experiment are shown in Table 2. The average $\dot{V}_{O_2}$ max of the subject groups were in the range 45.9~47.9 ml.kg^{-1}·min^{-1}. No significant differences were observed among the subject groups for the $\dot{V}_{O_2}$ max and its related parameters including V_E, RER and O_2 pulse at the point where the $\dot{V}_{O_2}$ max was achieved with the exception that the heart rate and the $\dot{V}_E/\dot{V}_{O_2}$ ratio at $\dot{V}_{O_2}$ max of group GT were significantly higher and lower than those of group GU, respectively. The leg strength (expressed as kg·kg^{-1} body weight) of group GT was significantly greater than that of groups PU and PT, and the anaerobic power of group GU was significantly lowest when compared with the other groups of subjects.

All the subjects finished their corresponding 8-wk experimental protocol without complications. The effects of exercise training, drug administration, or both combined, on physiological and physical fitness characteristics are shown in Fig. 1 and Table 3. The value of individual measured parameters of subjects in each group at the end of the 8-wk experiment was expressed as the percent of its corresponding 0-wk (initial) value, and comparison among groups was performed. After the 8-wk period of the experiment, percent body fat was significantly decreased from initial level in the ginseng treated subjects (groups GU and GT), but not in the placebo treated counterparts (groups PU and PT). The body fat levels of the groups PU, PT, GU and GT were 101.5± 3.6, 94.8± 3.2, 95.3± 2.1, and 91.8± 2.3% of the initial value, respectively (Fig. 1). However, no significant differences in the changes in this parameter among the subject groups were found except between group GT and group PU. Resting heart rate was significantly decreased from initial level in every group of subjects except group PU causing the change in this parameter in group PU significantly differed from the other subject groups, whereas the percent decrease in resting heart rate of group GT was significantly greater than that of group PT (Fig. 1). The resting heart rate of the groups PU, PT, GU and GT at the end of the 8-wk period were 100.3± 1.3, 95.4± 1.3, 93.4 ± 1.9, and 91.0± 1.4% of the 0-wk level, respectively.

Fig. 1 also illustrates the change in the aerobic capacity at the end of the 8-wk experimental period. All the subject groups, except group PU, showed significant increase from initial value in $\dot{V}_{O_2}$ max. The change in the $\dot{V}_{O_2}$ max in group GT was significantly greater than that in group GU but not that in group PT. The 8-wk level of V_{O_2} max of the groups PU, PT, GU and GT were 99.3± 1.6, 114.5± 4.3, 112.6± 3.1, and 124.5± 3.7% of the initial value, respectively.

Table 3 shows the changes in body weight, arterial blood pressure, and the characteristics of the aerobic and anaerobic capacity at the end of the 8-wk experimental period. Neither significant changes from the initial value in each subject group

Table 3. Changes in maximal aerobic and anaerobic exercise data of four subject groups after 8 wks of placebo or ginseng administration with or without physical training

	PU (n=10)	PT (n=11)	GU (n=10)	GT (n=10)
Body weight	100.1+ 0.5	100.3+ 0.9	99.9+ 0.5	100.7+ 0.5
Arterial blood pressure:				
– Systolic	102.9± 2.8	101.1± 2.3	104.3± 2.5	102.9± 1.9
– Diastolic	103.2± 4.8	102.9± 4.5	104.2± 5.3	104.5± 2.3
Values at V_{O_2} max:				
– Heart rate	99.5± 0.3	103.4± 0.7 [†a]	100.9± 0.3 [†ab]	102.3± 0.7 [†a]
– O_2 pulse	99.7± 1.0	114.8± 3.8 [†a]	113.8± 3.7 [†a]	118.7± 3.8 [†a]
– V_E	95.8± 3.3	123.7± 3.6 [†a]	123.5± 5.6 [†a]	129.5± 6.2 [†a]
– V_E/V_{O_2} ratio	97.2± 3.7	110.9± 1.2 [†a]	112.3± 5.4 [†a]	111.6± 2.4 [†a]
– RER	99.8± 1.0	99.2± 1.1	98.8± 0.9	99.9± 1.3
Leg strength	94.5± 4.6	119.7± 2.5 [†a]	119.1± 4.9 [†a]	135.9± 9.0 [†a]
Anaerobic power	103.6± 1.5 [†]	109.5± 1.9 [†a]	113.1± 1.6 [†a]	108.6± 2.2 [†]
Anaerobic capacity	104.4± 1.0 [†]	108.9± 1.6 [†a]	107.2± 1.5 [†]	106.6± 0.8 [†]

Values are means± SEM. Data are presented in percent of the initial (0 wk) values. See Table 1 for explanation of abbreviations for the subject groups.

[†] Significantly different from 0 wk (at least $p<0.05$). Absolute values at the 0 wk (shown in Table 1) and 8 wk of the experiment were used for the statistical tests.

[a,b] indicate significant differences from PU and PT, respectively (at least $p<0.05$).

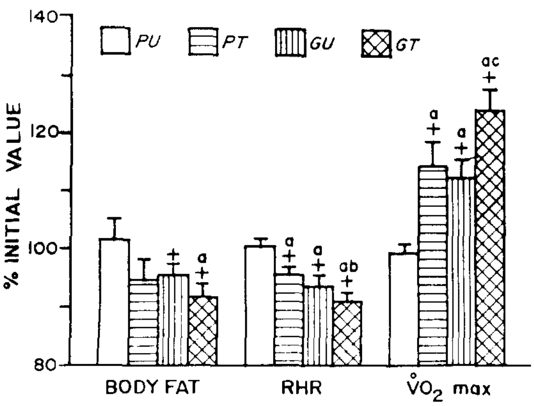

Fig. 1. Changes in body fat, resting heart rate (RHR), and maximum oxygen uptake ($\dot{V}_{O_2}$ max) of four subject groups after 8 wk of placebo or ginseng administration with or without physical training. Data are presented in percent of initial (0 wk) values. PU=placebo-untrained (n=10), PT=placebo-trained (n=11), GU=ginseng-untrained (n=10), GT=ginseng-trained (n=10). Values are means± SEM. a, b, and c indicate significant differences from PU, PT, and GU, respectively (at least $p<0.05$). + indicates significant difference from 0 wk values (at least $p<0.05$).

nor significant differences among all the subject groups for body weight and arterial blood pressure were found. All the subject groups, except group PU, showed significant increases from initial value in exercising heart rate, O_2 pulse, $\dot{V}_E$, and $\dot{V}_E/\dot{V}_{O_2}$ ratio at the point where the $\dot{V}_{O_2}$ max was achieved. No significant change in RER at V_{O_2} max was found in each group of subjects. Comparison among the PT, GU, and GT groups for the percent changes in heart rate, O_2 pulse, V_E, $V_E/\dot{V}_{O_2}$ ratio, and RER at the time where the V_{O_2} max was achieved showed no significant differences with the exception that the value for the heart rate at V_{O_2} max was significantly lower in group GU when compared with group PT.

All subject groups except group PU showed significant increases in their leg strength, but no significant differences were observed among groups PT, GU and GT for such the improvement although the mean value of the change in leg strength was highest in group GT (Table 3). Table 3 also shows that anaerobic power and anaerobic capacity were significantly increased over initial levels in all subject groups, but no significant differences among groups were observed except for groups PT and GU which exhibited significantly greater changes in anaerobic power ($p<0.05$ and $p<0.001$, respectively) and group PT exhibited significantly changes in anaerobic capacity ($p<0.05$) when compared with group PU.

Discussion

Exercise training under the regimen used in this study reduced resting heart rate and enhanced maximum aerobic power in the placebo-treated subjects. Such changes could be contributed to the effect of exercise since placebo administration without training exhibited no significant effect on both resting heart rate and $\mathring{V}_{O_2}$ max. It is of interest that daily administration of standardized ginseng extract for 8 weeks gave improvement in aerobic fitness similar to that observed in response to exercise training.

It is known that regular endurance exercise training induces adaptations at both the central (the circulatory) and peripheral (the exercising muscle) levels which are responsible for the increase in aerobic work capacity. The central adaptations include an increased blood volume, greater maximal exercise stroke volume and cardiac output, which enhance the oxygen transport capacity.[11-14] The peripheral adaptations are manifested with an increase in capillary density, a greater mitochondrial density, and increases in oxidative phosphorylation enzyme activities, which are responsible for enhancement of the oxidative capacity of exercising muscle.[11,14,15] In the present study, the changes in various physiological parameters related to the maximum aerobic power such as the heart rate, O_2 pluse, minute ventilation, and respiratory equivalent for oxygen under exhaustive exercise test in the ginseng-treated subjects were similar to those of the trained subjects. It is possible that the improvement in cardioventilatory functions and hence the oxygen transport capacity in response to exercise training chould also have occurred through the administration of the ginseng extract under the conditions of the present experiment. Previous investigations[3,4] have also reported the positive effect of the standardized ginseng extract on physical performance such as pulmonary function, exercising and recovery heart rate and blood lactate, and maximum O_2 consumption which correspond to the results of the present study and testify the improvement in physical fitness. However, the exact mechanism responsible for such the training-like effects of the standardized ginseng extract on the aerobicity is still unknown. It is possible that the drop of resting heart rate in subjects treated with ginseng might be due to the effect of the drug since it has been reported from animal studies that all of the active constituents of ginseng (ginsenosides) could induce bradycardia.[1]

It has also been reported that anesthetized dogs, when injected intravenously with an aqueous extract of ginseng, had their cardiac output, stroke volume, and central venous pressure significantly decreased although total peripheral resistance increased.[1] Since it was found in the present study that $\mathring{V}_{O_2}$ max was enhanced by ginseng administration and since maximum cardiac output is an important determinant of $\mathring{V}_{O_2}$ max, it is possible that such depressing effect of ginseng on cardiac output found in anesthetized dogs should not occur during exhaustive exercise in the present study.

Although the exercise training program of the present study had a significant effect on aerobic capacity but had no significant effect on body weight or percent body fat. The result is in agreement with a previous experiment on humans exercised at intensity and duration similar to the present study.[16]

This suggests that any caloric deficit created through energy expenditure for exercise was balanced by a proportionate increase in energy intake. It is possible that the caloric cost of exercise in this study was small. In contrast with training, ginseng administration with untrained subjects for 8 weeks caused a significant decrease in percent body fat. The effect was a little more marked when the exercise training and ginseng administration were combined. This might suggest that metabolism of nutrients especially lipid was modified by the ginseng extract but not, or small if any, by training in the direction of more utilization of body fat. However, it is unknown whether such metabolic effect of the ginseng was due to its direct or indirect action.

It was shown by the present experiment that endurance training with cycle ergometer enhanced leg muscle strength. This finding was in agreement with a previous study which has reported that moderate levels of physical activity tend to improve muscle strength.[17] Surprisingly, the present study also showed that the leg muscle strength was increased by ginseng in untrained subjects and tend to be more enhanced in the trained ones. The possible physiological mechanisms underlying strength improvement in response to training have been proposed as the results of adaptaion of the nervous system or the muscle themselves,[18] it remains unknown, however, how the ginseng caused improvement in muscle strength.

In addition to muscle strength, maximum anaerobic power and anaerobic capacity were also increased after exercise training in this study. Although these two anaerobic fitness parameters of the untrained subjects treated with placebo were enhanced with unknown causes, the improvement in these types of anaerobic fitness in exercise groups was more marked. It has been suggested that a gain in muscle strength brought about by training can explain improvements in anaerobic capacity.[18] Since the maximum anaerobic power and anaerobic capacity and the leg muscle strength were increased by endurance exercise training and since the training and the Wingate test of anaerobic exercise capabilities used the same cycling activity and hence the same leg muscle groups, perhaps such improvement in the anaerobic fitness is related to the gain in muscle strength. Similar to training, administration of the standardized ginseng extract improved both the anaerobic power and anaerobic capacity. However, only the increase in anaerobic power but not anaerobic capacity was significantly greater in the ginseng-treated subjects when compared to the placebo-treated ones. Maximum anaerobic power represents the power created anaerobically by splitting of adenosine triphosphate and creatine phosphate (phosphagen), while maximum anaerobic capacity represents the maximal capacity to produce energy from the phophagen and glycogen.[18] Thus, the apparent increase in the maximal rate of anaerobic work production (anaerobic power) by ginseng might have resulted from an increase in muscle stores of phosphagen. However, the mechanism responsible for this remains unknown.

The results of the present experiment indicate that there were no clear synergistic effects of the exercise training and the administration of the ginseng extract on all the measured physical fitness variables when the two treatments were combined in a single experiment, although some variables such as resting heart rate and maximum O_2 consumption showed high trend of synergistic actions when compared to the effect of individual treatment. It is possible that the rate of improvement of physical fitness by treatment with either training or ginseng administration in subjects under the conditions of the present study is relatively limited so that one treatment could not provide a strong stimulation for a more pronounced increment in physical fitness of the other. However, no evidence existed in the present study could support this statement since the effects of either higher dose of ginseng or more severe training or both were not examined.

In conclusion, the results of the present study with healthy young males indicate that ginseng administration produced training-like effects on $\mathring{V}_{O_2}$ max and improved anaerobic power and muscle strength. However, clear synergistic action on these fitness parameters could be observed when both ginseng administration and exercise training were combined.

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