Dietary Supplementation with Astaxanthin-Rich Algal Meal Improves Strength Endurance – A Double Blind Placebo Controlled Study on Male Students –

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The present study was designed to investigate the effect of dietary supplementation with astaxanthin on physical performance. Forty healthy paramedic students were recruited for this test in a double blind placebo controlled study. In this study, we used algal meal (AstaREAL® biomass) as astaxanthin supplementation. Twenty of the subjects received capsules filled with algal meal to provide 4 mg astaxanthin per capsule, whereas the other twenty received placebo capsules for six months. The physical parameters monitored were fitness, strength/endurance and strength/explosivity by standardized exercises. Before starting the dietary supplementation, base values for each of the subjects were obtained. At the end of the six month period of dietary supplementation, the average number of knee bendings (squats) increased by 27.05 (from 49.32 to 76.37) for subjects having received astaxanthin and by 9.0 (from 46.06 to 55.06) for the placebo subjects. Hence, the increase in the astaxanthin supplemented group was three times higher than that of the placebo group (P=0.047). None of the other parameters monitored differed significantly between the groups at the end of the study period. Based on this findings, it suggested that supplementation of astaxanthin is effective for the improvement of strength endurance that may lead to sports performance.

1. Introduction

Astaxanthin, a red carotenoid pigment, is a natural food factor that occurs naturally in a wide variety of living organisms such as algae, fish, and birds. It is a strong antioxidant, and astaxanthin has many highly potent physiological activities, such as antioxidative activity [1-3], anti-inflammation [4], anti-hypertension [5], anti-diabetic [6], anti-obese [7], anti-tumor and anti-cancer effects [8], memory improvement [9], amelioration of age-related maculopathy [10], ameliorative effect on accommodation and asthenopia [11].

Recently, astaxanthin has been reported to suppress muscle fatigue. Sawaki *et al.* reported about the effect of astaxanthin on sports performance [12]. In the report, improvements of visual acuity and muscle fatigue of human were characterized. Especially, in term of muscle fatigue, there was decreasing tendency of creatine kinase value (CK) in blood of exercised humans after astaxanthin supplementation compared to controls. In addition, there was significant decrease of lactic acid level in blood of exercised humans after astaxanthin supplementation. Because CK and lactic acid levels in blood are well-known biomarkers of fatigue, these results suggested that astaxanthin has suppressive effect on human muscle fatigue.

In animal experiments, Aoi *et al.* reported that astaxanthin limits exercise induced muscle damage in mice [13]. They also reported that astaxanthin improves muscle lipid metabolism in combination with exercise [14] by protecting carnitine parmitoyl-transferase I in the mitochondria membrane from oxidation. Ikeuchi *et al.* reported that astaxanthin supplmentation leads to increased muscle endurance in mice measured as swimming time to exhaustion [15]. This result suggested that astaxanthin has an anti-muscle-fatigue effect.

These researches suggest that astaxanthin is beneficial material for promotion of physical performance. However, there is no report about clinical data directly referring the improvement of numerical value of human physical performance, such as endurance and explosivity. In this study, we investigated the effect of dietary supplementation with astaxanthin on human physical performance. This is the first report showing the beneficial effect of astaxanthin on human strength/endurance performance.

2. Materials and Methods

2.1 Astaxanthin

The astaxanthin used in this study was homogenized and spray dried biomass of the green unicellular alga *Haematococcus pluvialis*, AstaREAL®, supplied by BioReal (Sweden) AB. The astaxanthin was packed in pigmented and sealed hard gelatin capsules to provide 4 mg astaxanthin per capsule. Starch was used as placebo and it was packed in identical looking capsules. The dietary supplementation comprised of one capsule daily taken orally in conjunction with a meal. Information regarding the

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contents of the capsules was not given to the individuals or to the supervisor of the experiment until after the end of the experiment.

2.2 Subjects

The subjects were young healthy male (the majority aged 17-19 years) students at a paramedical school. They were not subjected to any medication. The students (n=40) were randomly divided into two groups of equal size. One group was the experimental group receiving astaxanthin, and the other group was the placebo group. The subjects were encouraged to exercise normally and to lead a normal life during the experimental period. No further controls of the training conditions were performed.

During the experimental period, three individuals were discarded – one due to illness, one due to major orthopedic surgery, and one due to moving abroad (2 of the placebo and 1 of the experimental group).

2.3 Experimental Designs

Standardized exercise tests were carried out before starting the dietary supplementation, and after three and six months of dietary supplementation with the capsules. At each of these occasions blood serum hemoglobin (Hb) was measured and a health control was carried out.

Fitness, strength/endurance and strength/ explosivity were the physiological test parameters monitored.

During the entire experimental period, each individual made an assessment of his well being on a scale from 1 to 10 (1=awful, 5=normal and 10= excellent). The assessments were handed in to the test supervisor once every month.

2.4 Fitness

Fitness was determined through sub-maximum load until steady state pulse (the Åstrand method) was achieved. The test was carried out by a step-up exercise with a bench of 32 cm height at a pace of 25 step-ups per minute using a metronome. Each individual carried a gas tube set (Interspiro 324) weighting 17 kg used for smoke diving. Steady state pulse was achieved when during one minute deviation in heart rate compared to the previous minute was less than 3. Steady state pulse was achieved by all individuals within 6-9 minutes.

2.5 Strength/Endurance

Strength/endurance was determined as the maximum number of knee-bendings by each individual in a so-called "Smith machine (Tesch and Kaiser O.R.T, Sweden)" in standardized conditions. Warming up before the fitness exercise was carried out by biking on an ergometer bike according to a standard protocol (load 125 W for 3 minutes).

The knee-bending (squatting) was performed by bending knees to a 90°angle controlled by an adjustable stool. During the exercise the individuals carried barbell weighing 42.5 kg.

2.6 Strength/Explosivity

Strength/explosivity was estimated in standardized conditions using a Wingate machine with individually adjusted load and registration of maximum effect during 30 seconds. The standardized warm-up before this exercise was biking on an ergometer bike (5 minutes at 150 W followed by 3 minutes at 200 W and idling for 5 minutes at 50 W). The Wingate exercise comprising biking with a load calculated individually on the basis of the body weight (75 g/kg body weight). The test included maximum effort for 5 seconds – rest/slow biking for 60 seconds – maximum effort for 30 seconds. The effect was measured during these 30 seconds, which were followed by biking at own speed.

3. Results and Discussion

There was no difference between the two experimental groups in the fitness. There was also no difference in the Hb values between the two groups. Both groups gained weight during the experiment (placebo on average +2.1 kg and the astaxanthin group on average +1.0kg). The difference was not statistically significant. These increases in body weight would seem logical considering the age of the individuals. Likewise, there was no difference between the experimental groups in terms of steady state pulse, which decreased by on average 1.31/min in the placebo group and by on average 1.75/min in the test group.

In the strength/explosivity (Wingate test), there was a non-significant reduction in the total effect per kg body mass (W/kg) in both groups. The reduction in the placebo group was on average 5.81 and in the test group 4.13. Since many of the individuals exercise by running and playing ball games, these reductions can be explained by the poor training conditions out-doors during the experimental period.

There was a significant difference in strength/ endurance between the two experimental groups (Fig. 1).

The number of knee-bendings increased in both groups. After 6 months, the increase was 9.00 ± 6.28 more knee-bendings in the placebo group, whereas it was 27.05 ± 6.12 more knee-bendings in the test group compared to base line. According to least square means analysis of the data with an alpha=0.05, the confidence range of the test group was 14.6374 – 39.4679 and for the placebo group -3.7554 – 21.7554. According to difference of least square means analysis P=0.047.

There was no difference in the subjective assessment of the well being between the experimental groups. Neither was there a significant difference in terms of absence from school between the groups.

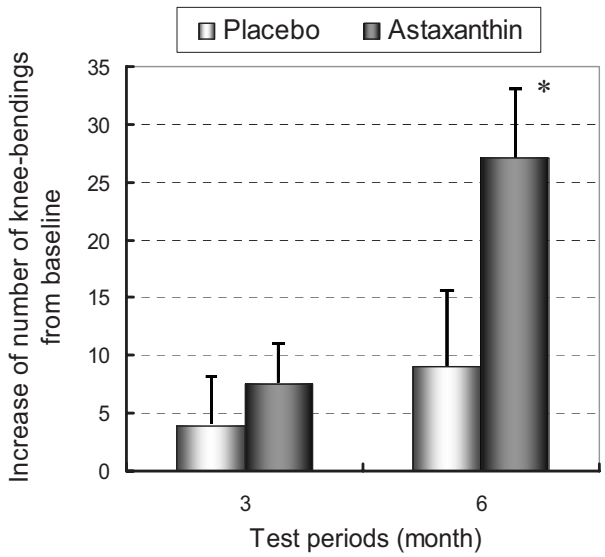

Fig. 1 Increase number of knee-bendings from baseline (0 month) in placebo and astaxanthin supplemented group. **p*=0.047 *vs*. placebo

The marked improvement in strength/endurance would seem very interesting, since it cannot be explained by an improved fitness (step-up test) or improved lactic acid tolerance (Wingate test). Furthermore, since there was no significant increase in body weight, an increased muscle mass cannot be used to explain this positive effect. Because of them, astaxanthin seems to have beneficial effect on strength/endurance.

This is the first study in humans to show that astaxanthin supplementation has positive effect on physical performance. The result of this study is supported by earlier findings that astaxanthin supplementation in mice increase swimming time before exhaustion [15] and that biomarkers of muscle fatigue decrease in humans after exercise due to supplementation [12].

Further studies need to be designed to find explanations to the mechanisms behind the increased muscle endurance. It can be hypothised that astaxanthin protects the membrane structures of the cells, like mitochondrial membrane [14], against oxidative stress generated during heavy exercise and thereby preserve the functionality of the muscle cells.

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5. References

[1] Miki, W., *Pure & Appl. Chem.*, **63**, 141-146, 1989.
[2] Shimizu, N., Goto, M., Miki, W., *Fisheries Science*, **62**, 134-137, 1996.
[3] Nishida, Y., Yamashita, E., Miki, W., *Carotenoid Science*, **11**, 16-20, 2007.
[4] Ohgami, K., Shiratori, K., Kotake, S., Nishida, T., Mizuki, N., Yazawa, K., Ohno, S., *Invest. Ophthalmol. Vis. Sci.*, **44,** 2694-2701, 2003.
[5] Hussein, G., Nakamura, M., Zhao, Q., Iguchi, T., Goto, H., Sankawa, U., Watanabe, H., *Biol. Pharm. Bull.*, **28**, 47-52, 2005.
[6] Naito, Y., Uchiyama, K., Aoi, W., Hasegawa, G., Nakamura, N., Yoshida, N., Maoka, T., Takahashi, J., Yoshikawa, T., *BioFactors*, **20**, 49-59, 2004.
[7] Ikeuchi, M., Koyama, T., Takahashi, J., Yazawa, K., *Bioschi. Biotechnol. Biochem.*, **71**, 893-899, 2007.
[8] Chew, B.P., Park, J.S., Wong, M.W., Wong, T.S., *Anticancer Res.,* **19**, 1849-1853, 1999.
[9] Zhan, X., Pan, L., Wei, X., Gao, H., Liu, *J., Environ. Geochem. Health*., **29**, 483-489, 2007.
[10] Parisi, V., Perillo, L., Tedeschi, M., Scassa, C., Gallinaro, G., Capaldo, N., Varano, M., *Retina*, **27**, 879-890, 2007.
[11] Nagaki, Y., Mihara, Y., Tsukahara, H., Ono, S., *Rinsho Iyaku*, **22**, 41-54, 2006.
[12] Sawaki, K., Yoshigi, H., Aoki, K., Koikawa, N., Azumane, A., Kaneko, K., Yamaguchi, M., *Rinsho Iyaku*, **28**, 1085-1100, 2002.
[13] Aoi, W., Naito, Y., Sakuma, K., Kuchide, M., Tokuda, H., Maoka, T., Toyokuni, S., Oka, S., Yasuhara, M., Yoshikawa, T., *Antioxidants and Redox Signaling*, **5**, 139-144, 2003.
[14] Aoi, W., Naito, Y., Takanami, Y., Ishii, T., Kawai, Y., Akagiri, S., Kato, Y., Osawa, T., Yoshikawa, T., *Biochem. Biophys. Res. Commun*., **366**, 892-897, 2008.
[15] Ikeuchi, M., Koyama, T., Takahashi, J., Yazawa, K., *Biol. Pharm. Bull.*, **29**, 2106-2110, 2006.