Applications for Athletes


Astaxanthin improves muscle lipid metabolism in exercise via inhibitory effect of oxidative CPT I modification.


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Intracellular redox balance may affect nutrient metabolism in skeletal muscle. Astaxanthin, a carotenoid contained in various natural foods, exerts high antioxidative capacity in the skeletal muscles. The present study investigated the effect of astaxanthin on muscle lipid metabolism in exercise. ICR mice (8 weeks old) were divided into four different groups: sedentary, sedentary treated with astaxanthin, running exercise, and exercise treated with astaxanthin. After 4 weeks of treatment, exercise groups performed treadmill running. Astaxanthin increased fat utilization during exercise compared with mice on a normal diet with prolongation of the running time to exhaustion. Colocalization of fatty acid translocase with carnitine palmitoyltransferase I (CPT I) in skeletal muscle was increased by astaxanthin. We also found that hexanoyl-lysine modification of CPT I was increased by exercise, while astaxanthin prevented this increase. In additional experiment, we found that astaxanthin treatment accelerated the decrease of body fat accumulation with exercise training. Our results suggested that astaxanthin promoted lipid metabolism rather than glucose utilization during exercise via CPT I activation, which led to improvement of endurance and efficient reduction of adipose tissue with training.

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Applications for Athletes: Endurance
Effects of astaxanthin supplementation on exercise-induced fatigue in mice.

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The present study was designed to determine the effect of astaxanthin on endurance capacity in male mice aged 4 weeks. Mice were given orally either vehicle or astaxanthin (1.2, 6, or 30 mg/kg body weight) by stomach intubation for 5 weeks. The astaxanthin group showed a significant increase in swimming time to exhaustion as compared to the control group. Blood lactate concentration in the astaxanthin groups was significantly lower than in the control group. In the control group, plasma non-esterfied fatty acid (NEFA) and plasma glucose were decreased by swimming exercise, but in the astaxanthin group, NEFA and plasma glucose were significantly higher than in the control group. Astaxanthin treatment also significantly decreased fat accumulation. These results suggest that improvement in swimming endurance by the administration of astaxanthin is caused by an increase in utilization of fatty acids as an energy source.

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Applications for Athletes: Endurance
Astaxanthin limits exercise-induced skeletal and cardiac muscle damage in mice.


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Dietary antioxidants may attenuate oxidative damage from strenuous exercise in various tissues. Beneficial effects of the antioxidant astaxanthin have been demonstrated in vitro, but not yet in vivo. We investigated the effect of dietary supplementation with astaxanthin on oxidative damage induced by strenuous exercise in mouse gastrocnemius and heart. C57BL/6 mice (7 weeks old) were divided into groups: rested control, intense exercise, and exercise with astaxanthin supplementation. After 3 weeks of exercise acclimation, both exercise groups ran on a treadmill at 28 m/min until exhaustion. Exercise-increased 4-hydroxy-2-nonenal-modified protein and 8-hydroxy-2'-deoxyguanosine in gastrocnemius and heart were blunted in the astaxanthin group. Increases in plasma creatine kinase activity, and in myeloperoxidase activity in gastrocnemius and heart, also were lessened by astaxanthin. Astaxanthin showed accumulation in gastrocnemius and heart from the 3 week supplementation. Astaxanthin can attenuate exercise-induced damage in mouse skeletal muscle and heart, including an associated neutrophil infiltration that induces further damage.

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Applications for Athletes: Prevention of Skeletal and Cardiac Muscle Damage
Sports Performance Benefits from Taking Natural Astaxanthin Characterized by Visual Acuity and Muscle Fatigue Improvement in Humans

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The effects of astaxanthin on visual acuity and muscle fatigue were studied. Astaxanthin (3,3'-Dihydroxy-.BETA.,-.BETA.-carotene-4,4'-dione) is a red pigment found in salmon and krill and has strong antioxidant properties. In the two supplementation studies, astaxanthin extracted from algae (Haematococcus pluvialis) was used. Four visual acuity parameters were examined in experiment A in 18 healthy adult male volunteers that were equally divided into two groups (treatment and control). The measured parameters were deep vision, critical flicker fusion, static and kinetic visual acuity before and after supplementation. A second investigation (experiment B) involved 16 adult male volunteers to establish the effect of astaxanthin supplementation on the build up of lactic acid before and after running 1200 metres. In both experiments, the treated groups ingested an astaxanthin capsule per day for 4 weeks (6mg astaxanthin per day) and the control groups received a placebo capsule. Results: In experiment A, the deep vision and the critical flicker fusion of the treated groups were significantly improved compared to the control group. No effects of treated group were observed on static and kinetic visual acuity. In experiment B, serum lactic acid concentration at 2 minutes after activity (1,200m running) of the treatment group was significantly lower than that of the control one. No other effects related to supplementation of astaxanthin on serum biological and hematological examinations were observed. Based on these preliminary findings, it suggested that supplementation of astaxanthin is effective for the improvement of visual acuity and muscle fatigue that may lead to sports performance benefits.

Applications for Athletes: Visual Acuity and Muscle Fatigue

**Haematococcus astaxanthin: health and nutrition applications: Exercise survey with 88% reporting improvement**

Guerin, M, Huntley, M, Olaizola, M.

“In March 2001, a health survey looked at the various positive effects of Astaxanthin on exercise. The survey involved 247 between the ages of 20 and 87 years. 146 of those taking part reported problems with muscle and joint soreness. When taking Astaxanthin, 88% of participants reported improvement. In all cases, the more exercise an individual did, the more benefit was experienced.”

Applications for Athletes: Muscle and Joint Soreness
**Inhibition of Oxidative Injury of Biological Membranes by Astaxanthin**

Michi Kurashige, Eiji Okimasu, Masayasu Inoue and Kozo Utsumi

The value of astaxanthin, a carotenoid pigment, in the treatment of oxidative injury is assessed. Astaxanthin protects the mitochondria or vitamin E-deficient rats from damage by Fe²⁺ catalyzed lipid peroxidation both in vivo and in vitro. The inhibitory effect of astaxanthin on mitochondrial lipid peroxidation is stronger than that of α-tocopherol. Thin layer chromatographic analysis shows that the change in phospholipid components of erythrocytes from vitamin E-deficient rats induced by Fe²⁺ and Fe³⁺-xanthine/xanthine oxidase system was significantly suppressed by astaxanthin. Carrageenan-induces inflammation of the paw is also significantly inhibited by administration of astaxanthin. These data indicate that astaxanthin functions as a potent antioxidant both in vivo and in vitro.

Applications for Athletes: Mitochondria (Energy Producing Part of Cells)
Astaxanthin protects mitochondrial redox state and functional integrity against oxidative stress.


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Mitochondria combine the production of energy with an efficient chain of reduction-oxidation (redox) reactions but also with the unavoidable production of reactive oxygen species. Oxidative stress leading to mitochondrial dysfunction is a critical factor in many diseases, such as cancer and neurodegenerative and lifestyle-related diseases. Effective antioxidants thus offer great therapeutic and preventive promise. Investigating the efficacy of antioxidants, we found that a carotenoid, astaxanthin (AX), decreased physiologically occurring oxidative stress and protected cultured cells against strong oxidative stress induced with a respiratory inhibitor. Moreover, AX improved maintenance of a high mitochondrial membrane potential and stimulated respiration. Investigating how AX stimulates and interacts with mitochondria, a redox-sensitive fluorescent protein (roGFP1) was stably expressed in the cytosol and mitochondrial matrix to measure the redox state in the respective compartments. AX at nanomolar concentrations was effective in maintaining mitochondria in a reduced state. Additionally, AX improved the ability of mitochondria to remain in a reduced state under oxidative challenge. Taken together, these results suggest that AX is effective in improving mitochondrial function through retaining mitochondria in the reduced state.

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ASTAXANTHIN SUPPLEMENTATION

A.C. Fry, B.K. Schilling, L.Z.F. Chiu, N. Hori, and L.W. Weiss, FACSM.

Abstract
PURPOSE: To determine the effects of astaxanthin anti-oxidant supplementation as a counter-measure for delayed onset muscular soreness (DOMS) in currently trained individuals, nine weight trained males (X+SE: age=25.1+1.6 yrs., hgt=1.79+0.02 m, wgt=86.8+4.4 kg) participated in this study. METHODS: All subjects provided muscle biopsy samples from the vastus lateralis m. prior to inducing DOMS in the knee extensor mm. (10 sets x 7-10 reps, 85% eccentric 1 RM). The subjects ingested either 4 mg.d-1 of astaxanthin (Suppl; n=4) or a placebo (Con; n=5) for a 3 week loading phase prior to the DOMS-inducing protocol, and during a 12 d recovery phase. Perceptions of DOMS at 48 hrs post-eccentric exercise were quantified by muscle soreness ratings (0-10 Likert scale). Muscle fiber characteristics were determined via mATPase histochemistry and digital imaging to determine % cross-sectional areas of the major fiber types (I, IIA, IIAB/B). Due to small numbers of IIB fibers in some subjects, IIAB hybrid fibers were included in this fiber type population. Simple regression was used to determine relationships between fiber characteristics and perceptions of soreness. RESULTS: No differences in perceptions of soreness between the Suppl or Con groups were observed (p>0.05), with all subjects exhibiting a mean score of >5. Percent fiber type areas were similar (p>0.05) for both groups (type I, Suppl=47.6+8.9%, Con=41.3+2.7%; type IIA, Suppl=44.3+5.6%, Con=53.0+2.8%; type IIAB/B, Suppl=8.2+3.6%, Con=5.7+1.6%). However, 48 hrs after the DOMS-inducing session, perceptions of soreness for the Suppl group were positively related to % area type I (r=0.90), and negatively related to % area types IIA (r=-0.80) and IIAB/B (r=-0.99). A distinctly different correlational pattern was observed for the Con group (% type I area, r=-0.58; % type IIA area, r=0.32; % type IIAB/B area, r=0.40). CONCLUSIONS: Collectively, these preliminary data suggest that astaxanthin supplementation may preferentially attenuate perceptions of DOMS in weight trained men with a high % area for fiber types IIA & AB/B.

Applications for Athletes: Delayed Onset Muscle Soreness
Effects of Astaxanthin on Recovery from Whole Fatigue with Three Stepwise Exercises

NAGATA AKIRA; TAJIMA TAEKO; HAMAMATSU HOZUMI

This study was designed to evaluate the effects of astaxanthin (A) ingestion upon recovery from whole fatigue, that were generated by progressive loads of three stepwise exercise-30%HRmax, 50%HRmax, and 70%HRmax. Nineteen healthy volunteers were randomized into two groups: Group A (10 subjects) received oral astaxanthin capsule (5mg) daily for two weeks, while Group C (9 subjects) ingested oral placebo (C) capsule (5mg) with the double blind method. After a month from this ingestion, another capsules were taken again with cross-over system for the same subjects respectively. Comparative detections were practiced to estimate with effectiveness of A ingestion upon changing ratios between two groups. Significant difference between A and C groups were obtained to inhibit the increase of respiratory-circulatory function from expired gases analysis. Additionally sympathetic nervous activities (LF/HF ratio) during exercise and parasympathetic nervous activities (HF/TF 100) during recovery were observed to significant increase. Otherwise, blood serum concentration of LDL cholesterols showed significant decrease, while concentration of creatine phosphokinase had increased to higher level than that of C ingestion, significantly. Then, findings of the present study indicated that with astaxanthin ingestion for human, respiratory-circulation ability and activities of sympathetic nervous system were augmented to make efficient metabolism during exercise load. Those anti-fatigue and anti-oxidative function might be promoted for human to make recovery ability from the whole fatigue generated by exercise stress.

Applications for Athletes: Recovery
Effect of Astaxanthin on Muscular Atrophy

Tateo Sugiura, Yoshiharu Iida, Hisashi Naito, Daijiro Ohmori, Katsumasa Goto, Toshitada Yoshioka

Objective: Patients wearing casts or other devices that hinder mobility are reported to have muscular atrophy. It is commonly thought that the cause is from reactive oxygen species (ROS). The use of Vitamin E, along with other antioxidants, prevents ROS from causing muscular atrophy that arises from lack of movement; however there has been conflicting reports on its effectiveness, varying from some claiming that it works and others that it does not.

Results and Analysis: Groups that were administered Ax had significantly less muscle atrophy than those in the Control group (p<0.05). The level of Cu/Zn-SOD expressed was higher in the rats with casts than those without casts in the control group; however, in the Ax group, the level expressed was insignificantly different from those with casts and those without. In addition, the level expressed in the control group with casts was significantly higher than the Ax group with casts on. The level of calpain and ubiquitin expressed was higher in the control group with casts than those in the Ax group with casts, but the difference was insignificant. Also, significantly less (of calpain and ubiquitin) was expressed in the Ax 0.2% with casts compared to the control group with casts. The same pattern was seen with Cathepsin L expression. Presently, it is reported that muscular atrophy in patients who are immobile due to casts was caused by oxidative stress. The increase in oxidative stress accelerates the reaction of lipoperoxide, which causes distress in the cell membrane and sarcoplasmic reticulum, leading to an increase in Ca2+ in the cytoplasm and concurrently causing a decrease in its discharge. An increase in Ca2+ concentration activates calpain along with cathepsin. In addition, the presence of lipoperoxide causes disruption in the cell membrane of the mitrocondria, causing iron ions and ROS to leak in the cytoplasm, which leads to ubiquitination (of proteins.) Ax is the same as beta-carotene in that they are both carotenoids. They both prevent lipoperoxides from disturbing the cell membrane in many biological organisms, but Ax is more active than other antioxidants. Based on this information, we believe Ax intake prevents muscular atrophy by protecting membranes; preventing oxidative stress which results in atrophy; preventing the facilitation protease and ubiquitination. The effects due to the quantity of Ax uptake were not clear in this study.

Applications for Athletes: Muscular Atrophy
Long term dietary antioxidant intakes attenuate sarcopenia

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Oxidative stress is thought to be one of significant contributing factors to age-related sarcopenia. We tested the hypothesis that the long term dietary antioxidant (astaxanthin intakes attenuate sarcopenia. Wistar strain male rats, aged 45 weeks old, were given either control (Cont) or astaxanthin feed (0.004%, Ax) for 1 year. The soleus muscle weights and muscle weight-to-body weight ratios in Ax group were significantly heavier than in Cont group, but tibialis anterior muscle mass remained similar between the two dietary groups. The level of ubiquitinated proteins was significantly lower in soleus muscles of Ax group, but not in tibialis anterior muscles when compared with Cont group. Tibialis anterior levels of cathepsin L and caspase-3 were tended to be lower in Ax group than in Cont group, especially significant differences observed in cathepsin L, whereas no differences between Cont and Ax were observed in soleus tbcas levels. There were no effects of Ax supplementation on calpains 1 and 2, UBC3B, CulZn SOD and nitrotyrosine levels in both soleus and tibialis anterior muscles. Our data suggest that the long term dietary astaxanthin intakes attenuate the age related muscle atrophy, due in part, to reductions in oxidative stress and ubiquitination of myofibrillar protein in slow soleus muscles, but not in fast tibialis anterior muscles.

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

Curt L. Malmsten and Åke Lignell

The present study was designed to investigate the effect of dietary supplementation with astaxanthin on physical performance. Fortyeight 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.

Applications for Athletes: Strength & Endurance
Title: Effects of Astaxanthin Supplementation on Exercise-Induced Fatigue in Mice

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Abstract: The present study was designed to determine the effect of astaxanthin on endurance capacity in male mice aged 4 weeks. Mice were given orally either vehicle or astaxanthin (1.2, 6, or 30 mg/kg body weight) by stomach intubation for 5 weeks. The astaxanthin group showed a significant increase in swimming time to exhaustion as compared to the control group. Blood lactate concentration in the astaxanthin groups was significantly lower than in the control group. In the control group, plasma non-esterfied fatty acid (NEFA) and plasma glucose were decreased by swimming exercise, but in the astaxanthin group, NEFA and plasma glucose were significantly higher than in the control group. Astaxanthin treatment also significantly decreased fat accumulation. These results suggest that improvement in swimming endurance by the administration of astaxanthin is caused by an increase in utilization of fatty acids as an energy source.

Applications for Athletes: Endurance
Effects of Astaxanthin Ingestion on Exercise-Induced Physiological Changes


Abstract
The purpose of this study was to evaluate the effects of astaxantin (ACT) ingestion on exercise-induced physiological functions. In this experiment we planned to investigate the autonomic nervous system (ANS) and the respiratory metabolism during different exercise intensities in subjects taking astaxantin and those taking placebo. The design of this experiment was a double-blind crossover study.
Eighteen male volunteers (35.8 ± 4.51 years of age) took ACT or placebo (CON) capsule daily for two weeks. Exercise stress tests were done before and after the ingestion period. The exercise load was in the form of running exercise on a treadmill at intensities of 30%, 50% and 70% of maximum heart rate (HRmax). Heart rate variability (HRV), expired gases analysis and blood biochemical parameters were measured. Sympathetic nervous activity (SNA) and parasympathetic nervous activity (PNA) were estimated from the pattern of power density in three frequency ranges on the power spectrum.
During the exercise at an intensity of 70% HRmax, CV_RR and HF/TF increased significantly (p<0.05) after ACT ingestion. Additionally, V_e decreased significantly (p<0.05) during exercise at 70% HRmax after ACT ingestion. These data indicated that after ACT ingestion, SNA was decreased and PNA was enhanced during exercises at 70% HRmax. Furthermore LDL cholesterol decreased markedly after exercise (p<0.05) and respiratory quotient decreased during exercise. These results suggest that ACT may contribute to enhancement of lipid metabolism. Decrease of respiratory parameters may indicate augmentation of the efficacy of exercise in energy metabolism.

Applications for Athletes: Energy Metabolism