

Natural Astaxanthin's Benefits for Athletes, Strength and Energy Levels

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Introduction

Astaxanthin is an excellent nutrient for athletes and active people; it can help them in several important ways. There have been ten different human clinical trials demonstrating a variety of benefits specifically applicable for athletic people. Among these include studies done at universities and at leading research institutions. One of the most exciting studies was sponsored by Gatorade®, the world's leading company in the field of sports drinks. The research encompasses work done in USA, Japan and Europe. Along with these ten human clinical trials are twenty-five supporting pre-clinical trials done in mammals and in-vitro.

The positive effects from daily supplementation with Astaxanthin are extremely diverse. With regards to athletes, the main emphasis of the research to date is on how Astaxanthin can improve recovery from exercise; enhance energy levels; and increase strength and endurance. But other benefits such as preventing pain and soreness after heavy workouts are also important for active people and athletes. And there are other known benefits of Astaxanthin supplementation that can be of great value to certain subsets of athletes; one exciting benefit in this category is Astaxanthin's ability to prevent damage to skin from UV exposure which is of particular import to athletes participating in outdoor activities such as long distance runners and bicyclists.

Among the principal functions of Astaxanthin are its intense antioxidant function and its broad spectrum anti-inflammatory activity. Both of these attributes are critical to Astaxanthin's benefits for athletes. Physical exertion is known to generate a tremendous increase in reactive oxygen species (ROS) in our bodies. As far back as 1978 researchers suggested that physical exertion creates damage to tissues as a result of free radical proliferation. The increase in ROS occurs during both the contraction and resting of muscles. Intense exercise over a long training session or running a marathon for instance can result in oxidative damage to both lipids and proteins in the body. "Interestingly, low and physiological levels of reactive oxygen species are required for normal force production in skeletal muscle, but high levels of reactive oxygen species promote contractile dysfunction resulting in muscle weakness and fatigue" (Powers and Jackson, 2008). Hence, a powerful, effective antioxidant such as Natural Astaxanthin can effectively scavenge these high levels of ROS in our bodies and prevent weakness and fatigue.

As an anti-inflammatory, Natural Astaxanthin can also make a big difference for athletes in preventing joint and muscle soreness after exercise, thus allowing for better training with less down time. Recovery after exercise is a huge concern for athletes, and Astaxanthin's antioxidant as well as its anti-inflammatory activity both help promote quicker recovery and can help with overuse injuries.

To fully understand Astaxanthin's benefit for athletes, we will first analyze its antioxidant power, and then look more fully into its anti-inflammatory activity. We will then visit each of the ten human clinical trials related to athletes. Finally, we will briefly summarize some of the most substantial pre-clinical animal trials supporting the human research.

The World's Strongest & Highest Quality Natural Antioxidant

Astaxanthin has been tested head-to-head in many experiments on antioxidant strength against several other carotenoids and antioxidants; it has consistently come out as the very strongest of all natural antioxidants in these tests regardless of the type of test. For example, whether examining free radical elimination or singlet oxygen quenching, Astaxanthin's power as an antioxidant comes out far beyond the capacity of other antioxidants. This is really amazing when you think about it, since many of the antioxidants Astaxanthin has been tested against are closely related molecules in the carotenoid family. Yet Astaxanthin usually comes out superior by at least a power of ten. And when comparing with vitamin antioxidants such as Vitamin C and Vitamin E, Astaxanthin has been shown to be as high as 550X to 6000X stronger!

Yet, as we'll examine below, it is not only that Astaxanthin is so much stronger than other antioxidants that makes it unique; Astaxanthin also has four remarkable qualitative properties that separate it from other antioxidants. When taking together both its quantitative and qualitative properties, it quickly becomes crystal clear that Astaxanthin is the best antioxidant we can take to supplement our diets and would provide any athlete with a distinct advantage.

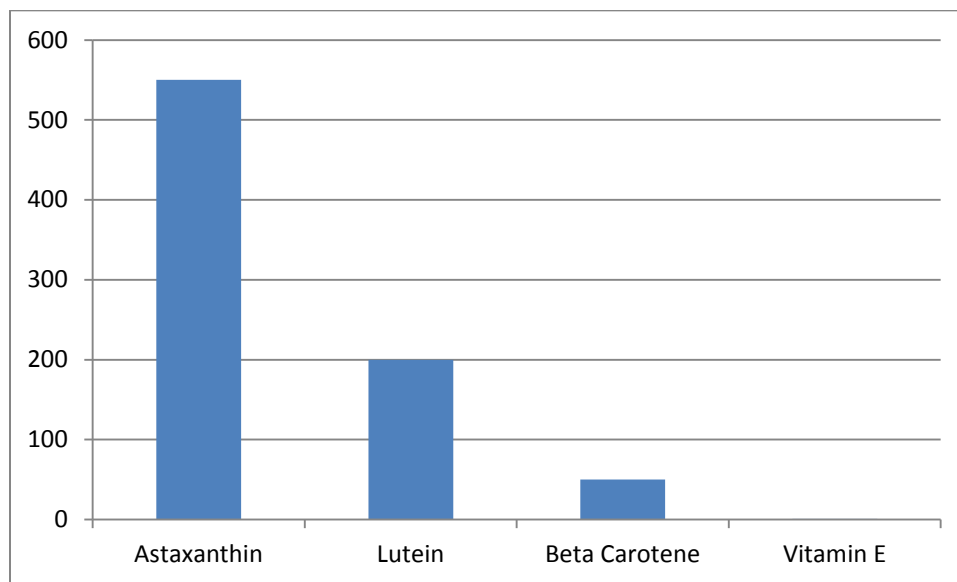
Quantitative Differences Between Astaxanthin and Other Antioxidants: As far back as the 1940's, scientists had discovered the antioxidant abilities of carotenoids and had identified Astaxanthin as being extremely potent in this respect. Research in France in 1946 found that Astaxanthin and beta-carotene were both powerful antioxidants, with Astaxanthin being the stronger of the two (Herisset, A., 1946). Pioneering researchers in the area of eye health discovered Astaxanthin's superior antioxidant protection for the eyes shortly afterward (Grangaud, 1951; Massonet, 1958).

By the 1990's, Astaxanthin's powerful antioxidant activity was becoming widely accepted. A paper published in Japan in 1991 set the platform for a flurry of research that would follow:

“Astaxanthin, one of the dominant carotenoids in marine animals, showed both a strong quenching effect against singlet oxygen and a strong scavenging effect against free radicals. These effects are considered to be defense mechanisms in the animals for attacking these active oxygen species. The activities of Astaxanthin are approximately 10 times stronger than those of other carotenoids that were tested, namely zeaxanthin, lutein, tunaxanthin, canthaxanthin and beta-carotene, and 100 times greater than tocopherol. Astaxanthin also showed strong activity as an inhibitor of lipid peroxidation mediated by these active forms of oxygen. From these results, Astaxanthin has the properties of a ‘Super Vitamin E’ (Miki, et al, 1991).

Dr. Miki must have been extremely impressed to call Astaxanthin a “Super Vitamin E;” during that period in the early 1990's, Vitamin E was considered by many to be about the most beneficial nutrient for both topical application and internal consumption. However, in finding that Astaxanthin was 10 times stronger as an antioxidant than its carotenoid cousins and 100 times stronger than Vitamin E, he must have felt that it deserved such a venerable title.

Many other experiments have been done since Dr. Miki's, all with the same results—Astaxanthin remains the most powerful natural antioxidant found to date. The volume of studies is far too great to review in their totality in a paper of this scope, so we will look at a few of the most important studies which will enable our readers to get a general idea of Astaxanthin's superior antioxidant strength. The first study we'll examine was also done in the 1990's and also in Japan. This study focused on singlet oxygen quenching. It pitted Astaxanthin against several other antioxidants including carotenoids such as lutein and beta carotene, and it also tested Astaxanthin against Vitamin E. The results were heavily favored toward Astaxanthin; lutein got within the same realm as Astaxanthin in this particular test, but beta carotene and particularly Vitamin E were far weaker than Astaxanthin.



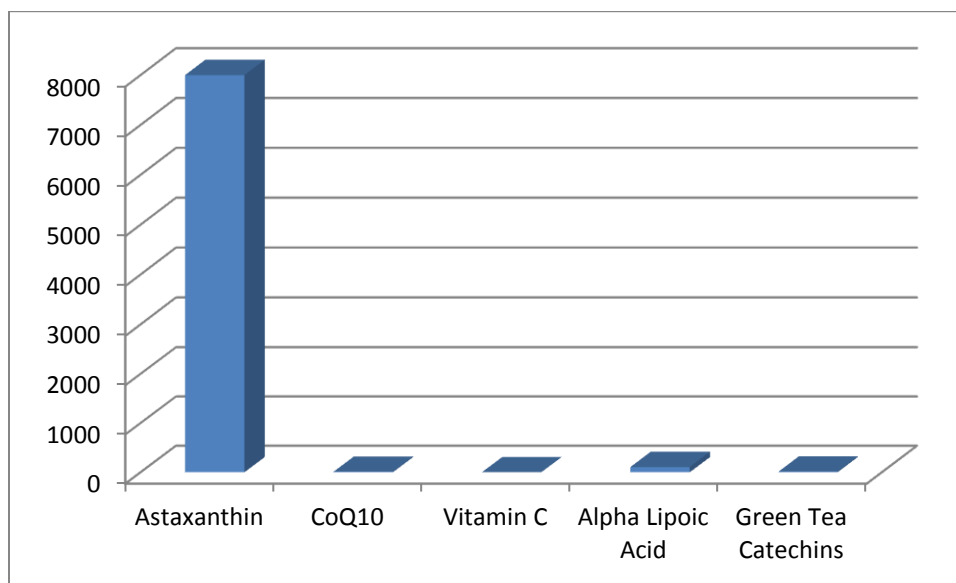
Singlet Oxygen Elimination (Shimidzu, Goto, Miki, 1996)

In singlet oxygen elimination, results of this study found Astaxanthin to be:

- 550 times stronger than Vitamin E
- 11 times stronger than beta-carotene
- 2.75 times stronger than lutein (Shimidzu, et al, 1996)

One of the authors of this study was Dr. Miki, the original researcher who did the oft-times quoted study from 1991 showing Astaxanthin to be phenomenally stronger than other antioxidants and calling it a “Super Vitamin E.” As a great fan of Astaxanthin, Dr. Miki participated in another study of Astaxanthin's strength against singlet oxygen many years later in 2007. This time they pitted Astaxanthin against a completely different set of antioxidants. The antioxidants evaluated in this study were Coenzyme Q10, green tea catechins, alpha lipoic acid and Vitamin C. The main difference between this study and Dr. Miki's earlier work is that the results were even more slanted in Astaxanthin's favor.

Many people consider CoQ10 an excellent antioxidant. And among vitamins, Vitamin C is also fairly highly regarded as an antioxidant. Yet when tested against Astaxanthin for their ability to eliminate singlet oxygen, Astaxanthin wasn't just superior—it was incredibly more potent.



Singlet Oxygen Quenching (Nishida, Yamashita, Miki, 2007)

As you can see from the chart above, none of the other antioxidants were even remotely close to Astaxanthin's capacity to eliminate harmful singlet oxygen. The closest of the four was alpha lipoic acid, yet Astaxanthin was still 75 times more potent. Results showed that Astaxanthin is:

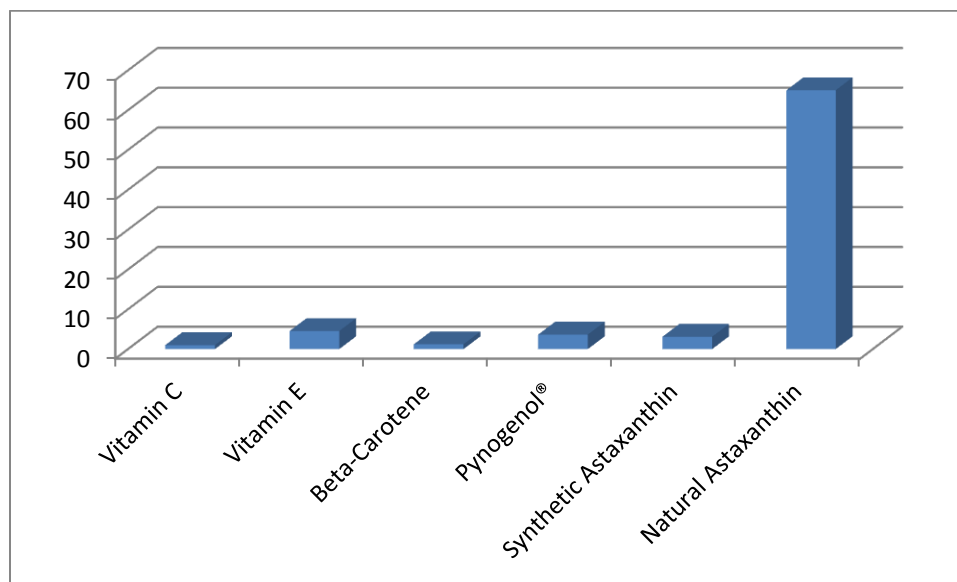
- 8000 times more potent than Vitamin C
- 800 times more potent than CoQ10
- 550 times more potent than Green Tea Catechins
- 75 times more potent than Alpha Lipoic Acid (Nishida, et al, 2007)

The last antioxidant research we'll review in this paper was done at Creighton University by a leading antioxidant and nutritional supplement researcher, Debasis Bagchi, PhD. Professor Bagchi is very well respected in his field with almost 300 publications including several books and hundreds of peer-reviewed studies. Incredibly, Dr. Bagchi's work has been cited by his colleagues over 12,000 times! And relevant to our discussion here, one of Dr. Bagchi's most interesting accomplishments is developing a very effective protocol for testing the free radical scavenging ability of antioxidants.

When comparing antioxidants, it is very important to analyze them head-to-head and to test them in different experiments. For example, a single test of Astaxanthin versus Vitamin E as a singlet oxygen eliminator is not a comprehensive view of the two different molecules' antioxidant capacity. Singlet oxygen are without a doubt extremely harmful to our cells over time, but they are just one of many different oxidants that wreak havoc in our bodies. The research in the 1990's focused primarily on Astaxanthin as a singlet oxygen eliminator, so Dr. Bagchi decided

to look at Astaxanthin from a different angle: He tested Astaxanthin head-to-head against other well-known antioxidants by measuring their ability to scavenge free radicals in a very well designed experiment.

While this research was originally done in 2001, Dr. Bagchi had great foresight and decided to test both Natural Astaxanthin and Synthetic Astaxanthin in this study even though Synthetic Astaxanthin was not available at the time as a human nutritional supplement. He pitted the natural and synthetic versions of Astaxanthin against Vitamin E, Vitamin C, beta-carotene, and he also included the trademarked supplement Pycnogenol® in the mix as it was claiming to be an extremely powerful antioxidant in its marketing literature. Although this was a completely different way to measure antioxidant strength from the earlier Miki studies, and this set of antioxidants included two completely new molecules—Synthetic Astaxanthin and Pycnogenol®—Natural Astaxanthin again came out the undisputed champion with antioxidant strength ranging from 14X greater than Vitamin E to 65X greater than Vitamin C.



Free Radical Elimination (Capelli, Bagchi, Cysewski, 2013)

Natural Astaxanthin was again far more potent than all other antioxidants. The results showed that, in free radical quenching, Natural Astaxanthin is:

- 14X stronger than Vitamin E
- 18X stronger than Pycnogenol®
- 21X stronger than Synthetic Astaxanthin
- 54X stronger than beta-carotene
- 65X stronger than Vitamin C (Capelli, et al, 2013a)

This university-based research led by one of the world's leading experts in the field accomplished three very important things:

- ✓ It proved the consistency of Astaxanthin's superior antioxidant strength regardless of how it is analyzed.
- ✓ It quantitatively proved that Astaxanthin is much stronger than other antioxidants that were claiming to be extremely powerful such as Pycnogenol®.
- ✓ It showed how incredibly different and more potent *Natural* Astaxanthin is than *Synthetic* Astaxanthin.

We see by the relationship between Astaxanthin and Vitamin E in the studies cited above how important it is to use more than one method of measuring antioxidant strength. In the singlet oxygen experiments in the 1990's, Astaxanthin was proven to be 550X stronger than Vitamin E. Yet, when Dr. Bagchi tested the two as free radical scavengers in 2001, Astaxanthin was shown to be 14X stronger. While 14X is still quite impressive, it is a far cry from 550X. So the question comes up as to which number is accurate. The answer is that both of these numbers are accurate, and Astaxanthin is 14 times better than Vitamin E in eliminating free radicals and 550 times better than Vitamin E in specifically eliminating singlet oxygen. It would be impossible to accurately give an exact number when comparing the two in "antioxidant strength," but if we had to pick a number, Dr. Miki's original estimate that Astaxanthin is 100X stronger than Vitamin E back in 1991 would probably be just about right. Which may be why Dr. Miki simplified things and started calling Astaxanthin a "Super Vitamin E."

A final, critical finding of this study is the clear superiority of Natural Astaxanthin to its distant relative, Synthetic Astaxanthin, in antioxidant strength. While a full review of the vast differences between these two molecules would be too comprehensive for this paper, it is important that our Readers understand that these are two completely distinct molecules. In fact, other than sharing the same chemical formula, they are almost exact opposites in all other respects. The primary differences between the two are:

- **Shape:** The Natural Astaxanthin molecule's stereochemistry is unique (it is shaped differently than the Synthetic Astaxanthin molecule).
- **Esterification:** Natural Astaxanthin is 95% esterified (it has a fatty acid molecule attached to either one or both ends of the molecule). Synthetic Astaxanthin is exclusively "free" Astaxanthin and does not have fatty acid molecules attached to it.
- **Synergy:** Natural Astaxanthin from *Haematococcus pluvialis* microalgae comes complexed in nature with supporting carotenoids. There are consistently small amounts of other antioxidant carotenoids such as lutein, beta-carotene and canthaxanthin ranging from 5% - 15% of the total carotenoid fraction which help provide a synergistic effect when ingested. Synthetic Astaxanthin does not contain supporting carotenoids.
- **Source:** Synthetic Astaxanthin is synthesized from petrochemicals in an elaborate process. Natural Astaxanthin is extracted from natural *Haematococcus pluvialis* microalgae.
- **Safety:** Natural Astaxanthin has an extensive portfolio of human safety studies and a history of over 15 years of safe use as a commercially-sold nutritional supplement. Synthetic Astaxanthin has never been directly tested in humans for safety. (As we'll review in the next section, this is an overriding concern due to serious safety issues with related synthetic carotenoids beta-carotene and canthaxanthin.)

- **Antioxidant Strength:** As noted above, Natural Astaxanthin is 20X stronger than Synthetic Astaxanthin as an antioxidant in scavenging free radicals. Another antioxidant head-to-head comparison has shown that Natural Astaxanthin is over 50X stronger than Synthetic Astaxanthin in singlet oxygen quenching (Capelli, et al, 2013a).
- **Efficacy:** Amazingly, Synthetic Astaxanthin has never been shown to have any health benefit in human clinical research. It is completely untested and may not have any health benefit at all. Natural Astaxanthin has been shown to have diverse health benefits in approximately 100 different positive human clinical trials.
- **Dosage:** In the event that Synthetic Astaxanthin is ultimately proven safe for long-range human consumption, dosages would logically be a minimum of 20 times greater than corresponding dosages of Natural Astaxanthin due to its vastly inferior antioxidant profile. This high dosage requirement would most likely put Synthetic Astaxanthin out of reach economically for most consumers.

Qualitative Differences Between Astaxanthin and Other Antioxidants: Astaxanthin is not only an incredibly powerful antioxidant, it is also a unique antioxidant in terms of how it works in our bodies. There are four distinct ways we can see these qualitative properties. While each of these independently would be a critical differentiator from other antioxidants in terms of health value and efficacy, the four of these taken together form a critical mass of evidence of Astaxanthin's superior qualitative antioxidant properties. Each of these is very impressive, and while hard to pick the most important or least, below we list these qualitative differences in the order of their relative importance in our opinion:

1. **Spans the cell membrane to protect the entire cell:** A general rule of antioxidants is: "Lipid soluble antioxidants protect the lipid (oil) soluble part of our cells, and water soluble antioxidants protect the water soluble part of our cells." So when we ingest Vitamin C which is water soluble, its antioxidant properties are useful in one part of our cells, and when we ingest Vitamin E which is oil soluble, its antioxidant properties are useful in the remaining part of our cells. The shape of the Astaxanthin molecule allows it to span the cell membrane and have one end of the molecule in the oil soluble part of the cell and the other end of the molecule in the water soluble part of the cell. This gives Astaxanthin the distinctive characteristic of being able to protect the entire cell. And Astaxanthin has been found capable of travelling throughout the entire body, into the bloodstream, muscle tissue, skin, as well as the various critical organs (Capelli and Cysewski, 2014). This double feature of being able to get throughout the body and being able to protect the entire cell makes Astaxanthin a super-effective antioxidant and anti-inflammatory for humans.
2. **Never a Pro-Oxidant:** A lot of very good antioxidants can, under certain conditions, turn into oxidants and start harming our cells. This is what happened in the famous "Finnish Smokers Study" on beta-carotene published in the prestigious "New England Journal of Medicine" in 1994. This study tested consumption of synthetic beta-carotene, which (like Synthetic Astaxanthin) is completely different from the natural form. Heavy smokers who were smoking on average three packs of cigarettes each day were supplemented with synthetic beta-carotene and found after time to have a slightly higher

incidence of cancer. This was amazing to all involved since dozens of epidemiological studies as well as pre-clinical research showed that beta-carotene has cancer-preventative properties (Moorhead, et al, 2005). What was happening was that the beta-carotene was turning into a pro-oxidant in the smokers' bodies because smoking depleted their Vitamin C levels. In the absence of Vitamin C, the beta-carotene molecules had no supporting antioxidants to pass off the supercharged free radicals caused by smoking, so they "changed teams" and became oxidants. This caused additional cellular damage, which in turn, increased the incidence of cancer (Heinonen and Albanes, 1994). "Without Vitamin C, beta-carotene can catch the destructive energy of a free radical and itself become a damaging molecule. In this situation, beta-carotene has entered a 'pro-oxidant' state. If Vitamin C is available this pro-oxidant state will quickly be converted back to an antioxidant state without damage to cells" (Malila, et al, 2006; Capelli and Cysewski, 2014).

Many other excellent antioxidants besides beta-carotene can become pro-oxidants under certain conditions. For example, well-known vitamin antioxidants such as Vitamins C & E, zinc, and even carotenoid antioxidants such as lycopene and zeaxanthin can all become pro-oxidants (Martin, et al, 1999). Fortunately, Astaxanthin can never become a pro-oxidant and cause damage to our cells (Beutner, et al, 2000).

3. **Crosses the blood-brain barrier and blood-retinal barrier:** A lot of very good antioxidants can't help protect our eyes and brains. Even carotenoid antioxidants that are closely related to Astaxanthin such as beta-carotene and lycopene can't get through these barriers that exist to protect our most vital organs from foreign matter. Since our brains are the control center for everything we think and do, an antioxidant that can't protect the brain seems to be of little value to us. Fortunately, Astaxanthin can get through the blood-brain barrier to protect our brains. When it reaches our brains, it can then travel through the blood-retinal barrier to help protect our eyes. Some of the earliest research on Astaxanthin back in the 1940's and 1950's showed Astaxanthin's ability to get into the eyes of rats (Grangaud, 1951 and Massonet, 1958); meanwhile, many human clinical studies have been completed over the last several years to confirm Astaxanthin's diverse health benefits for the eyes and brain (Capelli and Cysewski, 2014). And once present in the eyes and brain, it is not only Astaxanthin's antioxidant activity that is working prophylactically, but also its broad spectrum anti-inflammatory properties are providing additional protection to these vital organs. This one-two punch against oxidation and inflammation is exactly what brains and eyes need to stay healthy and function well.
4. **Bonds with muscle tissue:** As we mentioned above, Astaxanthin can get throughout the entire body and into all the critical organs. Of utmost import to athletes and active people, it can also bond with muscle tissue to protect muscles from increased levels of oxidation and inflammation and keep the muscles functioning smoothly.

If Astaxanthin only had one distinct advantage over other antioxidants, it would be unjustified to call it the "World's Highest Quality Natural Antioxidant;" however, with four important, documented advantages over more commonplace antioxidants, we feel it's perfectly warranted and that Astaxanthin has earned this title. Coupled with its broad spectrum anti-inflammatory

properties which we'll examine in the next chapter, it becomes clear that Astaxanthin is unquestionably the most useful antioxidant to consume as a dietary supplement and is highly recommended for athletes and active people.

A Safe & Natural, Broad-Spectrum Anti-Inflammatory

It is difficult to say whether Astaxanthin's anti-inflammatory properties or its antioxidant power is more important with regards to athletes; both are responsible for benefits that help athletes attain higher levels in their sports. Fortunately Astaxanthin is quite capable in both respects, leading to a variety of distinct advantages for the professional athlete, casual sportsman, weekend warrior and also for non-athletes who do hard physical work.

Astaxanthin works as an anti-inflammatory through multiple pathways. The various mechanisms of action for Astaxanthin as an anti-inflammatory have been demonstrated in several studies (Lee, et al, 2003; Ohgami, et al, 2003; Choi, et al, 2008; Kishimoto, et al, 2010). This research has consistently shown that Astaxanthin works on a variety of different causes of inflammation. In fact, there is evidence that it works on six different inflammatory markers, but that it works in a gentle, broad-spectrum manner. This is in distinct contrast to anti-inflammatory drugs such as Celebrex® and Vioxx® as well as over-the-counter anti-inflammatories such as NSAIDs (Tylenol®, Motrin®, Alleve®, etc.) and aspirin which target a single inflammatory marker, but in an intense manner. Inflammatory markers gently reduced by Astaxanthin include:

- Prostaglandin E-2
- Interleukin 1b
- Interleukin 6
- Tumor Necrosis Factor-A
- Nitric Oxide
- Cox 1 & 2 enzymes (Lee, et al, 2003; Ohgami, et al, 2003; Choi, et al, 2008; Kishimoto, et al, 2010)

Natural Astaxanthin has never been shown to have any side effect or contraindication in hundreds of medical research studies as well as over 15 years of commercial consumer use. There are countless safety studies such as acute toxicity and chronic toxicity studies showing that Natural Astaxanthin is completely safe and has absolutely no adverse side effects or contraindications (Capelli and Cysewski, 2014). Meanwhile, prescription anti-inflammatory drugs as well as over-the-counter anti-inflammatories all have serious side effects. Over-the-counter anti-inflammatory NSAIDs such as Tylenol, Motrin and Alleve can all cause serious liver and stomach problems, while aspirin can also harm the stomach lining and cause ulcers. The prescription drugs such as Vioxx and Celebrex are even more dangerous; Vioxx was taken off the market several years ago after causing an increase in heart disease and premature death in many users, while Celebrex remains on the market albeit with extensive warnings about its potential for adverse cardiovascular events.

Natural Astaxanthin is completely different from these other drugs. It takes significantly longer to work, but it has no side effects. The prescription and over-the-counter drugs can work the same day to combat pain, while Astaxanthin usually takes at least two weeks and up to six or even eight weeks to work; but once it starts working, users report that Natural Astaxanthin has the same positive effects on painful inflammatory conditions as the anti-inflammatory drugs, but without any side effects.

In addition to several human clinical trials, two consumer surveys have validated Natural Astaxanthin's ability to combat painful inflammatory conditions. In fact, one of these consumer surveys asked users to compare Natural Astaxanthin's anti-inflammatory effects to prescription and OTC anti-inflammatories and found that Natural Astaxanthin has similar results to those non-natural drugs:

- A survey of people with joint, muscle or tendon pain found that:
 - 84% had positive results from using Natural Astaxanthin
 - 83% experienced less pain
 - 60% had increased mobility
 - When asked how Natural Astaxanthin's effects compared to other anti-inflammatories found in the drug store:
 - 75% said that Natural Astaxanthin works the same or better than over-the-counter pain medications such as aspirin, Tylenol, Alleve or Motrin
 - 64% said that Natural Astaxanthin works the same or better than prescription anti-inflammatories such as Celebrex or Vioxx (Capelli, et al, 2008).
- In a consumer survey of 247 Natural Astaxanthin users, “over 80% of those reporting back pain and symptoms from osteoarthritis or rheumatoid arthritis reported an improvement from Astaxanthin supplementation. Astaxanthin supplementation was also reported to improve symptoms of asthma and enlarged prostate. All of these conditions have an inflammation component which is closely tied to oxidative damage” (Guerin, et al, 2002).

To summarize, it appears from these consumer surveys that Natural Astaxanthin works about as well as prescription and OTC anti-inflammatories. It does, however, take considerably longer to work. But the critical distinction is that Natural Astaxanthin has never been shown to have any side effects or contraindications—it's completely safe and natural—while OTC pain pills and prescription anti-inflammatories all have serious side effects, some that can end up killing you (Capelli and Cysewski, 2014). So the crucial decision is left up to the consumer: Do you want fast results that may end up seriously hurting you, or would you rather wait about a month for the same results and be safe and healthy?

Astaxanthin's Anti-Inflammatory Mechanisms of Action: Back in 2003, scientists working concurrently but independently in Japan and Korea were honing in on Astaxanthin's broad-spectrum mechanisms of action for combatting inflammation. Although they were not corresponding or sharing information, and even though they used very different paths to get there, both groups of researchers arrived at similar conclusions. This was the start, but other studies since then have further substantiated the early findings. Below is a summary of some of the most significant research in this area:

1. **First Study Proving Mechanism of Action:** Researchers at Japan's Hokkaido Graduate School of Medicine were the first to prove Astaxanthin's multiple mechanisms for controlling inflammation. They did their research in test tubes and also in rats, focusing

on the rats' eyes. They found that Astaxanthin reduced three key causes of inflammation: Nitric oxide (NO), tumor necrosis factor alpha (TNF-a) and prostaglandin E-2 (PGE-2) (Ohgami, et al, 2003).

2. **Second Mechanism of Action Study:** Later the same year, Korean researchers working independently found similar results to the Ohgami study in vitro and ex-vivo. In harmony with the Ohgami results, they found that Astaxanthin suppresses the inflammatory mediators nitric oxide, prostaglandin E-2 and tumor necrosis factor alpha. But they also demonstrated Astaxanthin's positive effects on three other inflammatory markers: Interleukin 1B, COX-2 enzyme and nuclear factor kappa-B (Lee, et al 2003).
3. **Further Validation:** Several years later, scientists from Korea University further validated the earlier results finding broad-spectrum anti-inflammatory activity (Choi, et al, 2008).
4. **"Remarkable" Results:** Japanese researchers referred to Astaxanthin's anti-inflammatory activity as "remarkable" and found a statistically significant reduction in six different inflammatory markers tested (Kishimoto, et al, 2010).
5. **Inhibition of Mast Cells:** Mast cells are the key initiators of inflammation. Research at Kyoto University showed an inhibitory effect of Astaxanthin in rats' mast cells (Sakai, et al, 2009).
6. **In the most recent study in this area,** Astaxanthin was found to be effective at protecting against UV-induced inflammation in a broad-spectrum manner. In fact, cell death that is frequently caused by UV exposure was significantly decreased in the Astaxanthin-treated cells (Yoshihisa, et al, 2014).

Human Clinical Research Demonstrates Astaxanthin's Positive Effects on Painful Inflammatory Conditions: There have been several human clinical trials showing that Astaxanthin reduces pain in joints, tendons and muscles in groups of patients suffering from chronic conditions as well as in healthy young men doing intense exercise. The variety of studies are strong support for Natural Astaxanthin's far-ranging anti-inflammatory effects—whether the pain is in the joints, the tendons or the muscles, Astaxanthin seems to be able to reduce it and make people feel better. But once again we must warn readers—don't expect it to work fast. You'll have to use Astaxanthin at least two weeks and more likely four to as much as eight weeks to get the desired results.

The other point we must warn our readers about is this: About 15 – 20% of the people who take Astaxanthin for pain don't obtain their desired results. This isn't very different from other anti-inflammatory products you find in a drug store; most of those don't work for 100% of the people 100% of the time either. The reason this happens with Astaxanthin is most likely due to different people's bodies having a different capacity to absorb carotenoids. Astaxanthin is a carotenoid, the family of molecules that includes other health-giving nutrients like lutein, lycopene, zeaxanthin and the most famous carotenoid, beta-carotene. When absorption of carotenoids is studied in humans, researchers find a huge disparity in people's ability to assimilate them. The range is massive—from about 5% absorption level up to over 90% absorption. So what is probably happening when someone takes Astaxanthin for a few months and doesn't feel a reduction in pain is that they are most likely in the very low absorption range. Their body may only be absorbing 5% of the Astaxanthin in the capsule they're taking, so even if they're taking 12mg per day (which is generally the upper level recommended by most brands), their body isn't

feeling the effects because so little is getting into their bloodstream. Meanwhile, a person whose body is absorbing at the upper end of the range is getting practically all the Astaxanthin they consume into their bloodstream where it can work its magic. This person could take as little as 2mg – 4mg per day and get an excellent result for painful conditions. Fortunately, with over 80% of people finding great results in the normal dosage range of 4mg – 12mg per day and considering that these benefits happen without any dangerous side effects, there is little reason for most people to try other pain remedies that may be unsafe.

We'll examine the inflammation studies that were done on athletes or while people were exercising in the next section, but now let's look at a few other human clinical trials on inflammatory conditions:

- Astaxanthin reduced pain levels and increased satisfaction with the ability to perform daily activities in sufferers of rheumatoid arthritis. Rheumatoid arthritis is a chronic painful condition with no cure; it is very difficult to treat compared to osteoarthritis. In this double-blind, placebo-controlled study, people in the treatment group took 12mg per day of Natural Astaxanthin over the course of eight weeks. Results showed a steady trend toward improvement in both pain levels and satisfaction from the beginning of the study to a midway point after four weeks, and then increasing improvement during the last four weeks of the study. During the first month, subjects found slight improvements on average. But by the end of eight weeks, the pain scores had dropped by 35% and the satisfaction scores improved by 40% in the group taking Astaxanthin (Nir and Spiller, 2002a).
- Another disease with no cure, carpal tunnel syndrome (abbreviated as “CTS” and also known as “repetitive stress injury” in some countries) affects up to 2% of Americans at any given time. This is a debilitating condition that causes pain in the wrists. Patients suffering from CTS were randomly separated into two groups. One group took 12mg per day of Natural Astaxanthin and the other group took a placebo. Similar to the study on rheumatoid arthritis, this study also lasted eight weeks with a mid-term assessment of pain levels after four weeks. Perfectly mimicking the results found by people with rheumatoid arthritis, the group taking Astaxanthin had good results after four weeks, but much more significant results after the full eight-week course of treatment. Pain levels were measured as well as the duration of pain. After eight weeks, these dropped by 41% and 36% respectively. Some of the people taking Astaxanthin reported that they were able to make major changes in their lifestyle due to the positive effects they experienced (Nir and Spiller, 2002b).
- The marker used by doctors to measure how much silent (also called “systemic”) inflammation is occurring in a person's body is called C-reactive protein (CRP). Silent inflammation has been singled out as a leading cause of many different diseases, most of them life threatening. A double-blind, placebo controlled human clinical trial was done to test Natural Astaxanthin's effect on CRP levels in healthy volunteers. The subjects took either 12mg per day of Natural Astaxanthin or a placebo for eight weeks. CRP levels were measured before and after the eight week supplementation period. Results were very good—in only eight weeks people taking Astaxanthin reduced their CRP levels by over 20%; meanwhile, people taking placebo saw a slight increase in their CRP levels (Spiller, et al, 2006a).

- A team from Washington State University led by long-time carotenoid researcher Boon Chew, PhD did a multi-faceted study on Natural Astaxanthin primarily to test its effect on the human immune response. They used young women in this randomized, double-blind and placebo-controlled study. They measured immune markers as well as DNA damage, oxidative stress levels and CRP. The results were positive on all markers. In fact, at a dose of only 2mg per day they found a statistically significant decrease in CRP levels after eight weeks of supplementation (Park, et al, 2010).
- In addition to the studies on CRP above, a company experimenting with Astaxanthin production back in 2006 publicized a human clinical trial on patients with CRP levels that were high enough to place them in a high risk category. The patients took Natural Astaxanthin or placebo for three months, after which their CRP levels were again measured. Nearly half of the people taking Astaxanthin fell out of the high risk category while none of those taking placebo did (Mera, 2006).

Human Clinical Research on Athletes and Active People

There have been some excellent human clinical trials showing an array of benefits for athletes and active people from Astaxanthin use. The research got going in the first few years of the new millennium, but studies have been appearing in publications more frequently over the last few years. To begin our review, we'll take a look at an excellent study that took place just a few months before this paper was written. This study was done on elite soccer players, and the results elicited were extremely exciting. We'll then look at a study from a few years ago that was sponsored by the world's leading sports drink manufacturer, Gatorade®, that involved competitive cyclists. We'll then go through the remainder of the ten human clinicals in the area of athletic performance and energy in order of relative importance.

Muscle Inflammation and Recuperation in Elite Soccer Players: Soccer is the world's sport—the most closely followed competitive sport in most countries around the globe. This study looked at the effect of Astaxanthin supplementation on young elite soccer players in Europe. The study was randomized and placebo-controlled; it spanned 90 days of supplementation. Shane Starling, a leading nutraceutical industry journalist, summed up the results very well:

“They gave 4mg of Astaxanthin daily to 40 young, trained soccer players and found via plasma testing better results for the Astaxanthin group in inflammation, immune system function and muscle recuperation...the researchers said the study showed Astaxanthin ‘attenuates muscle damage, thus preventing inflammation induced by rigorous physical training’” (Starling, 2015).

Concluding the study, the researchers hypothesized that the mechanism of action may be that Astaxanthin “protects the cell membranes against free radicals generated during heavy exercise, thus preserving the functionality of muscle cells” (Baralic, et al, 2015).

Gatorade® Sponsored Study Finds Competitive Cyclists Made Faster with Higher Power Output by Astaxanthin: When a company like Gatorade pays to do a study on how an ingredient affects competitive athletes, you can bet that they are fairly certain of the outcome before commissioning the study and making the investment. Gatorade looked at the existing research on Astaxanthin as the world's strongest natural antioxidant and as a proven broad spectrum anti-inflammatory, and they reviewed the earlier human trials on athletes, and then decided to sponsor this study to see if Natural Astaxanthin could make competitive cyclists faster and stronger. As expected, Astaxanthin worked great.

This study lasted only four weeks, a relatively short time for Astaxanthin to concentrate in the bodies of the athletes and improve their race times. It also was done at the very minimum dose generally recommended by Astaxanthin experts: 4mg per day. The researchers tested the cyclists in a 20 kilometer (about 12.5 miles) time trial before the supplementation began and again at the end of four weeks of supplementation. We must keep in mind that these were not

average people, but highly trained, competitive cyclists. Even marginal improvement from a supplement regimen after just four weeks would be an excellent result in this particular group of subjects.

At the end of four weeks, the placebo group showed no improvement in their cycling times. However, the cyclists taking Natural Astaxanthin were on average 5% faster. In addition, their power output increased by 15% (Earnest, et al, 2011). In just four weeks and at the very lowest recommended dosage, Natural Astaxanthin made these competitive cyclists significantly faster and stronger. Any athlete would love to have these fantastic results from just taking one small capsule each day. In order to really understand how much of a difference Astaxanthin can make to athletes, we'd like to see more research in this area, but with a longer study duration and at the upper range of dosage of 12mg per day.

Recovery from Exercise and Muscle Fatigue: A randomized, double-blind, placebo-controlled crossover study in Japan measured recovery from exercise in healthy volunteers. They had both the placebo and the Astaxanthin groups do progressively greater loads in a stepwise exercise. Again, the dosage was low (5mg per day), and remarkably, the study duration was extremely short (2 weeks). Examination was done on respiratory-circulatory function and blood analysis. They also measured sympathetic nervous activities during exercise and parasympathetic nervous activity during recovery.

All parameters tested showed significant improvements in the treatment group taking Astaxanthin. Metabolism during exercise became more efficient, respiratory-circulatory ability improved, and anti-fatigue and antioxidant profiles were augmented. These results led the researchers to conclude that recovery ability from exercise stress may be improved by taking Astaxanthin. Additional benefits from blood analyses were found: The Astaxanthin group had significantly less LDL cholesterol in their bloodstream and significantly higher creatine phosphokinase (Nagata, et al, 2003).

Increased Strength and Endurance Improvement in Healthy, Young Men: Natural Astaxanthin is the power generator that allows salmon to make their heroic upstream swim. Astaxanthin is found at the highest concentration in the animal world in salmon, and within the salmon the Astaxanthin concentrates in the muscles to allow the salmon to swim up raging rivers for over a week. This is the greatest endurance feat in all of nature, and it is fueled by Natural Astaxanthin.

Based on this fact, researchers in Sweden did a six month clinical trial on young, healthy men to see if Astaxanthin would have the same effect in humans that it did in salmon. They had the men do deep knee bends to exhaustion after a warm-up period. Again, the study featured a very low dose of Astaxanthin—only 4mg per day—but fortunately the study lasted six months, so the Astaxanthin had time to concentrate throughout the treatment group's bodies. Results showed that Astaxanthin increased strength and endurance by 62% in six months. The placebo group also showed improvement of 22%, which is normal for young people who are participating in sports over a six month period. But the relation between the two groups is what really counts—

strength and endurance increased three times faster in the young men taking Astaxanthin compared to the group taking placebo. The lead researcher, Dr. Curt Malmsten, summarized the results:

"The marked improvement in strength/endurance would seem very interesting, since it cannot be explained by 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 this, Astaxanthin seems to have the beneficial effect on strength/endurance.

This is the first study in humans to show that Astaxanthin supplementation has a positive effect on physical performance. The result of this study is supported by earlier findings that Astaxanthin supplementation in mice increases swimming time before exhaustion, and that biomarkers of muscle fatigue decrease in humans after exercise due to Astaxanthin supplementation.

Further studies need to be designed to find the explanations to the mechanisms behind the increased muscle endurance. It can be hypothesized that Astaxanthin protects the membrane structures of the cells, like the mitochondrial membrane against oxidative stress generated during heavy exercise and thereby preserves the functionality of the muscle cells" (Malmsten and Lignell, 2008).

Increased Strength in Patients Suffering from Tendonitis: The Malmsten study we reviewed above from Sweden was done on healthy, young men. This next study we'll look at was done in a group of people that were not healthy; these people were suffering from tennis elbow, a form of tendonitis that affects the arms.

The repetitive motion of hitting tennis balls with a racket can manifest as tennis elbow, which causes a loss of grip strength in the hands and pain while gripping objects in the hand. The clinical researcher responsible for studying Astaxanthin's effects on rheumatoid arthritis and carpal tunnel syndrome that we reviewed earlier did a different kind of study on people suffering from tennis elbow. His name is Gene Spiller, PhD. Dr. Spiller tested patients' grip strength and the pain in their hands from tennis elbow before and after Astaxanthin supplementation. Once again, he separated the sufferers into two different groups randomly. The first group took 12mg per day of Natural Astaxanthin for eight weeks, while the other group took an identical placebo. The results for people supplementing with Astaxanthin were outstanding: On average, their grip strength increased by almost double in only eight weeks. The average increase was 93% to be exact, and there was also a decrease in their self-assessment of pain in their hands. Dr. Spiller concluded that using Natural Astaxanthin may alleviate pain and increase mobility. "This improvement may greatly improve the standard of living for those who suffer from such joint disorders" (Spiller, et al, 2006b).

Reduced Muscle Fatigue from Lactic Acid Buildup During Exercise: Lactic acid builds up during physical exertion and causes burning in the muscles and fatigue. A study in Japan had healthy adult men take 6mg of Astaxanthin daily for four weeks. They had both the placebo and the Astaxanthin group run 1200 meters and tested their lactic acid levels before and after running at the beginning of the study (before supplementation began). They repeated this at the end of the study and found a statistically significant reduction in lactic acid buildup due to exercise in the men taking Astaxanthin. The result was excellent—a 28.6% reduction in lactic acid on average from taking 6mg of Natural Astaxanthin per day for a month (Sawaki, et al, 2002).

Prevention of Joint Soreness After Exercise: The first human clinical trial to test Astaxanthin's effectiveness against pain and inflammation was performed at the University of Memphis back in 2001 under the supervision of Andrew Fry, PhD. This study looked at Natural Astaxanthin's effect on healthy young men who were performing strenuous exercise.

Dr. Fry used a relatively low dose of Astaxanthin—only 4mg per day. Additionally, this study ran for a very short period of time—only three weeks. Dr. Fry wanted to see if Astaxanthin could help prevent the soreness that usually occurs after intense exercise. The young men who participated in this study were training regularly with weights. The subjects used a resistance-training apparatus for strenuous knee exercises during the three week treatment period and took either 4mg of Natural Astaxanthin or placebo every day.

The young men taking placebo had significant joint pain in their knees immediately after the exercise. This pain was tested 10 hours after the heavy exercise, and then again at 24 hours and 48 hours after the exercise. Whether immediately afterward or at the various test times up to and including 48 hours afterward, the pain persisted for those who took placebo. But the young men who were taking 4mg of Astaxanthin every day showed no change in knee soreness right after exercise. This pain-free state remained consistent at the three other test times of 10, 24 and 48 hours after exercise (Fry, A., 2001). This is a fantastic result in particular when you consider that the dosage was the lowest level commonly recommended and that the study only ran for three weeks. In research on chronic painful conditions that occurred after Dr. Fry's study, dosage was generally 12mg per day and the studies ran for eight weeks. After four weeks there was an improvement in pain levels, but it became much more pronounced after eight weeks as the Astaxanthin concentrated throughout the body. However, in the Fry study, the results were much quicker. The reason for this is not clear, but may have to do with the fact that these subjects did not start with painful conditions and were young and athletic. In any event, it is very important to understand that Natural Astaxanthin appears to reduce pain in people who suffer from chronic conditions, but also prevents pain in healthy people who are exercising heavily. The implications for not only the millions suffering from arthritis and tendonitis but also for athletes and regular people doing heavy work on a daily basis are extremely promising.

Prevention of Muscle Soreness After Exercise: The trial that Dr. Fry did at University of Memphis was originally focused on another inflammation-related condition. In fact, the main goal Dr. Fry had with the study was to see if Natural Astaxanthin could help prevent the soreness in muscles that occurs after doing heavy exercise. This condition is called "Delayed Onset

Muscle Soreness,” and it affects athletes, weight lifters, people doing hard physical work, and perhaps most notably, weekend warriors. Thankfully, the results he found about Astaxanthin preventing joint soreness are much more important than his original goal. There is no doubt that joint pain caused by strenuous exercise is a much more serious condition than muscle soreness that occurs after strenuous exercise. Pretty much everyone has had muscle soreness after a tough day in the garden or a long game of volleyball at the beach, and people are all highly aware that it’s just a temporary condition that will go away in a couple days. But sore joints are a much more troubling issue that are a greater concern than normal muscle soreness.

In any event, Dr. Fry did not immediately find a statistically significant result showing that Astaxanthin could prevent muscle soreness. But years later, Dr. Fry reexamined the data and found that in a subset of the subjects in this trial, Astaxanthin did have an excellent result in preventing muscle soreness after heavy exercise. The people that were positively affected were those whose muscles had high fiber content (Fry, et al, 2013). So basically, it appears that Natural Astaxanthin can prevent joint soreness after heavy exercise in most people, but it can only prevent muscle soreness after heavy exercise in some people.

Reduction of Respiratory Parameters and Improvement of Energy Metabolism: This Japanese double-blind crossover study tested several different parameters after working volunteers on a treadmill. The study only lasted two weeks, yet improvements in respiratory metabolism and energy metabolism were indicated. The study concluded that Astaxanthin supplementation may also contribute to the enhancement of lipid metabolism as LDL cholesterol decreased markedly after exercise (Tajima and Nagata, 2004).

Reduced Free Radical Production in Elite Soccer Players: The same group of researchers from Europe who did the first study we reviewed on elite soccer players did two preliminary human clinical trials before starting on their landmark study. The first of these preliminary studies tested whether Astaxanthin can reduce free radical production after intense two-hour long exercise. The treatment group took Astaxanthin for 90 days; as expected, the results were promising for Astaxanthin. The conclusion stated “Supplementation with Astaxanthin could prevent exercise induced free radical production and depletion of non-enzymatic antioxidant defense in young soccer players” (Djordjevic, et al, 2012).

Improvement of Oxidative Status in Young Soccer Players: The second preliminary clinical trial on young, European soccer players validated the results of the first preliminary trial: Astaxanthin supplementation led to improvement in oxidative status (Baralic, et al, 2013).

Supporting Pre-Clinical Research

Along with the excellent research in humans, there are many pre-clinical trials in mammals and in-vitro experiments supporting Astaxanthin's various benefits for athletes. In particular, an area of pre-clinical research that is very supportive of Astaxanthin's benefits for increasing energy levels is the study of how Astaxanthin affects the mitochondria of the cell. Mitochondria are commonly referred to as the "powerhouse of the cell." A major function of mitochondria is to produce ATP which is the "energy currency" of cells. Mitochondria are also responsible for regulating cellular metabolism (Voet, et al, 2006). We'll first look at studies about the mitochondria that validate Astaxanthin's energy boosting properties, and then we'll conclude this paper with a quick summary of some of the most important studies in mammals that support the human research we cited above.

Astaxanthin and Energy Production: Effects on the Mitochondria: There are many studies about how Astaxanthin can positively affect the cell's powerhouse, the mitochondria. We'll review some of the most relevant of these studies here:

- In a study done at University of Pittsburgh's School of Medicine, Astaxanthin protected against mitochondrial dysfunction and reactive oxygen species in a mouse model of Parkinson's disease and also in-vitro (Lee, et al, 2011).
- In perhaps the earliest study on Astaxanthin's effects on the mitochondria, Japanese researchers at Kochi Medical School found that Astaxanthin protects the mitochondria of rats better than a-tocopherol (Kurashige, et al, 1990).
- In a study done at Washington State University under the auspices of the famous carotenoid researcher Boon Chew, PhD, Astaxanthin prevented age-related mitochondrial dysfunction in dogs (Park, et al, 2013).
- Astaxanthin extended the lifespan of *C. elegans* (a model organism used in longevity studies) by protecting the mitochondria and the nucleus of the cells (Yazaki, et al, 2011).
- Astaxanthin can protect mitochondria that are subjected to oxidative stress. This study's abstract summarized the study:

"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 neurodegeneration and lifestyle-related diseases. Effective antioxidants thus offer great therapeutic promise...Astaxanthin at nanomolar concentrations was effective in maintaining mitochondria in a reduced state. Additionally, Astaxanthin improved the ability of mitochondria to remain in a reduced state under oxidative challenge. Taken together, these results suggest that Astaxanthin is effective in improving mitochondrial function through retaining mitochondria in a reduced state" (Wolf, et al, 2009).

- Astaxanthin was found capable of protecting the mitochondrial membrane and preventing DNA damage and cell-death in-vitro in a university study done in Taiwan (Chan, et al, 2009).
- Cells subjected to heat stress in-vitro were protected by Astaxanthin, which the researchers attributed to Astaxanthin's positive effect on the mitochondria (Kuroki, et al, 2013).
- In different studies on Astaxanthin's protective effects on of the mitochondria, it was found to be effective in benefiting various organs in different ways. The organs positively affected include:
 - Liver (Ma, et al, 2011; Song, et al, 2011)
 - Kidneys (Manabe, et al, 2008)
 - Heart (Nakao, et al, 2010)
 - Brain and central nervous system (Liu and Osawa, 2009; Liu, et al, 2009; Lu, et al, 2010)

Research in Mammals: There have been some very high quality rodent studies that substantiate the human studies related to athletes. We'll look at some of the top studies here:

- Last year researchers did a very promising study in rats which showed that Astaxanthin can delay physical exhaustion. In fact, it was so effective that the time to exhaustion in a swimming test was delayed by 29% (Polotow, et al, 2014). This would be of great interest to any athlete competing in endurance sports such as long distance running, triathlon and even high energy sports like basketball and soccer.
- An earlier study in mice came up with the same conclusion, but in this study they also measured blood lactose levels in both the control and Astaxanthin groups. The mice fed Astaxanthin had lower lactic acid levels in their muscles, which is most likely the main reason that they could swim significantly longer before exhaustion (Ikeuchi, et al, 2006).
- A study that was designed to investigate muscle lipid metabolism in mice found some very positive results that would be of interest to athletes. Mice in the Astaxanthin group had:
 - Better muscle lipid metabolism
 - Longer running time before exhaustion
 - Better fat utilization
 - Reduced fat tissue (Aoi, et al, 2008)
- The same lead researcher, Dr. Aoi, did a mouse study several years earlier that also had great relevance to athletes. Again, they ran mice on a treadmill until exhausted. The results they found were fantastic. Mice that were supplemented with Astaxanthin had:
 - Less oxidative damage in their heart muscles
 - Less oxidative damage in their calf muscles
 - Reduced oxidation in their plasma
 - Less DNA damage
 - Less peroxidation damage in their cell membranes
 - Decreased inflammation in their muscles by 50%

The study concluded: “Our data documented that Astaxanthin indeed is absorbed and transported into skeletal muscle and heart in mice, even though most carotenoids accumulate mainly in the liver and show relatively little distribution to other peripheral tissues, including skeletal muscle and heart. This unique pharmacokinetic characteristic of Astaxanthin makes it well suited to oxidative stress in gastrocnemius [calf] and heart...Thus, Astaxanthin attenuates exercise-induced damage by directly scavenging reactive oxygen species and also by down-regulating the inflammatory response” (Aoi, et al, 2003).

- In addition, Dr. Aoi’s latest work in this area found that Astaxanthin can reduce oxidative stress in muscles caused by exercise (Aoi, et al, 2014).
- Astaxanthin was found capable of improving lipid metabolism during exercise in mice. This study also tested inter-muscular pH levels and found that Astaxanthin was capable of preventing the normal decrease in pH levels due to exercise. Of particular import in this study was the finding that the mice fed Astaxanthin had an increase in muscles of PGC-1a, which is a key regulator of energy metabolism (Liu, et al, 2014).
- Finally, two rodent studies done in Japan have shown that Astaxanthin can prevent muscular atrophy. Muscular atrophy can be due to a few different causes; the most common cause is due to aging and another common cause is in people who have had part of their bodies immobilized in a cast. These studies addressed these two common causes of muscular atrophy:
 - Muscular atrophy due to aging is known as “sarcopenia.” Oxidation is thought to be a significant contributing factor to age-related saropenia. In a rat study done over the course of a year, rats were separated into two groups and fed either an Astaxanthin-enhanced diet or a control diet. The rats fed Astaxanthin had a muscle weight/body weight ratio significantly heavier than the control group. In other words, the aging rats’ muscles maintained their size when supplemented with Astaxanthin (Shibaguchi, et al, 2008).
 - Vitamin E, being a less powerful antioxidant, has been questionable in preventing muscular atrophy, so back in 2005, a group of researchers tested Astaxanthin as a supremely strong antioxidant against muscular atrophy. They immobilized rats’ muscles by applying casts, and then tested an Astaxanthin diet against a control diet. The study pointed out that Astaxanthin is more active than other antioxidants in preventing lipoperoxides from disturbing the cell membranes. The researchers believed that due to this effect, the experiment was successful. They hypothesized that “Astaxanthin prevents muscular atrophy by protecting membranes; preventing oxidative stress which results in atrophy; preventing facilitation protease and ubiquitination” (Sugiura, et al, 2005).

Conclusion

The body of evidence for Astaxanthin's benefits for athletes and active people has attained critical mass. It is very well documented as the world's strongest natural antioxidant, and it has been proven in many studies to be effective as an anti-inflammatory; both of these properties are critical to athletes in training. Whether the goal of the athlete is improved performance, increased strength and endurance, better recovery from workouts, more energy, decreased pain and soreness from exercise, or all of the above, he or she should seriously consider daily supplementation with a minimum of 4mg of Natural Astaxanthin. And for many of these athletes, it would be wise to take the upper level in the dosage range of 12mg per day.

The improved time trials for competitive cyclists in the Gatorade sponsored study is perhaps the best summary study for our review: Any athlete who would like to improve their cycling time by 5% and increase their power output by 15% in just four weeks has a great shot of attaining those goals simply by taking one 4mg Natural Astaxanthin capsule every day—that's what the results of the Gatorade study indicated. (And if they were to take 12mg each day and keep doing this long-range, they would probably have even better results.) Extrapolating the results of the Gatorade study out to other sports—runners & swimmers, soccer & basketball players, even power lifters & boxers—pretty much every athlete would love to get 5% faster and 15% stronger. For these reasons and the others cited throughout this paper, we conclude that every athlete should supplement their diets with Natural Astaxanthin.

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