

Collagen

Collagen is the primary structural protein in all animals, and it's the most abundant protein in mammals. (Yes, that means [humans] us, too.) It's the main component of connective tissue in our skin, bones, muscles, cartilage, tendons, blood vessels, and gut.

In short, collagen acts like a natural glue-like substance that our body constantly produces to hold our skeleton and internal organs in place. In fact, the word *collagenis* derived from the Greek word, κόλλα (*kólla*), meaning “glue”, and the suffix γέν (*gen*), which denotes “producing”.



However, something not so fun is that our body's natural collagen production starts to slow down as we age. In turn, things like saggy skin, wrinkles, aching joints, and muscle loss — among other signs of aging — are all linked to a lack of collagen production. All in all, collagen is not something we should take for granted; everyday decisions greatly impact our quality of life.

Unhealthy lifestyle choices, such as poor diet (high sugar consumption, processed foods), lack of exercise, high sun exposure, excessive alcohol consumption, and smoking can significantly diminish the body's ability to produce collagen. [1, 2, 3] In turn, unhealthy choices make us [look and feel] older, faster.

Now that we know how to avoid setbacks in terms of collagen production — or quality of life, for that matter — let's go ahead and expand on this topic.

The purpose of this information is to empower each reader to improve his/her quality of life by providing the most important information relevant to collagen. Below is a list of topics to be discussed:

- **Amino Acid Composition**
- **Top 8 Health Benefits**
- **Types of Collagen**
- **Bioavailable Food Sources (plus benefits of each particular source)**
- **Vitamins and Minerals that Promote Healthy Collagen Production**
- **Supplements**

As you can see, the discussion opens with amino acid composition. Try to bear with me on this part, as the primary amino acids in collagen will be noted periodically throughout this guide.

Amino Acid Composition

There are 20 amino acids that can be found in proteins, while precise amount and sequence is determined by a distinct genetic code assigned to each particular organism. [4] Collagen is composed of a triple helix structure, with an unusual abundance of three amino acids exhibiting over half of its composition (i.e., glycine, proline, and hydroxyproline). [5]

The most common motifs in its amino acid sequence are:

- **glycine-proline-X**
- **glycine-X-hydroxyproline**

(Note: X denotes any amino acid other than glycine, proline, or hydroxyproline.)

Glycine

A principle component of collagen, glycine, makes up about 35% of its amino acid composition (most abundant amino acid in collagen). [6] While it's the smallest amino acid in terms of size, glycine is massive in terms of its significance throughout the body. It contributes to a multitude of complex functions, such as muscle growth, joint support, digestion, cognitive function, and immune support, among others.

Proline

The second-most abundant amino acid in collagen, proline, appears in about one-of-six residues along the amino acid sequence (about 17% overall composition). Proline is a receptor to glycine and primarily functions as a precursor to collagen synthesis, since it stimulates the biosynthesis of procollagen (discussed further below). [7, 8]

Hydroxyproline

Hydroxyproline is derived from proline through hydroxylation (biochemical process to aid cross-linking of alpha peptides). This stabilizes procollagen (triple helical structure), whereas a lack of hydroxylation loosens it, which causes impaired collagen formation and scurvy. [9] Once procollagen has been tightly wound to form the triple helix, it's then transferred to the Golgi apparatus for modifications prior to completing collagen synthesis.

Top 8 Health Benefits

In terms of answering our golden question—what is collagen—this is arguably most important section. Some core benefits were alluded to earlier, but our discussion below reveals why collagen is far more than just beneficial. Our longevity (and livelihood, for that matter) is entirely dependent on the presence of collagen.

1. Provides joint support, reduces pain and inflammation.

Collagen forms a smooth, gel-like structure around our bones. In turn, this supports joints for optimal function and pain-free mobility. On the contrary, however, things like swollen joints, stiffness, and lack of mobility are all a result of insufficient collagen production. This happens with age, joint disorders, injuries, or even excess stress on the joints from physical activity.

Numerous studies have shown that hydrolyzed collagen (also referred as “collagen hydrolysate”) is a viable treatment for osteoarthritis and similar joint pain disorders. [10, 11, 12, 13] Additionally, hydrolyzed collagen has even been shown to reduce activity-related pain experienced by athletes, which has implications for all people who lead an active lifestyle. [14] All in all, collagen is proven to keep our joints spry.

2. Enhances skin health.

Collagen is the main component of the connective tissues in our skin. Thus, when the body is producing a sufficient amount, skin appears vibrant, moist, and tight. On the contrary, decreased collagen causes skin to droop, loosen, crack, wrinkle, and become dry. [15] It even makes us more susceptible to wounds, while also decreasing our natural wound-healing ability. [16]

Luckily, research indicates that oral intake of collagen reduces hallmark signs of aging in our skin. It has been shown to reduce wrinkles, cracking, and dryness, among others. [17, 18, 19] In short, collagen gives our skin a plump, moist, and silky smooth texture. It provides buoyancy, while also keeping the skin tight, yet elastic to protect against significant wounds.

3. Strengthens hair, nails, and teeth.

Collagen supplements are often labeled as beauty products, particularly as a hair, skin, and nails formula. These supplements should mention teeth, too, but no worries — that’s what we’re here for.

Similar to our skin, as we just discussed, collagen is a building block for hair, nails, and teeth. [20] Sufficient production helps grow, strengthen, and maintain natural shine in our hair; it also preserves a smooth, clear surface for our nails and teeth — opposed to a weak, granular surface that is susceptible to cracking. But unfortunately, we cannot escape the natural decline in collagen production as we age. Go ahead and blame balding, white or gray hair, dull and/or cracked nails, and even loss of teeth on lack of collagen.

If the natural decline has struck, perhaps these findings will be of interest. Collagen has been shown to reduce cracking in nails; research also suggests it can be used to improve the appearance of dry and/or dull hair, along with our skin, as mentioned. [21] Studies have even found collagen to be a therapeutic target for hair loss. [22]

4. Improves quality of sleep.

About 30% of the population suffers from insomnia, but collagen can help solve our sleep dilemma. According to research findings, taking 3 grams of glycine (primary amino acid in collagen) before bedtime improves quality of sleep and reduces fatigue the following day. [23]

Also note, collagen is roughly 35% glycine, about 9 grams gives us the amount of glycine necessary for better sleep (about 3 grams of glycine), based on these findings.

5. Promotes healthy digestion.

As mentioned, the fibrous protein structure of collagen forms connective tissues throughout the body — including the gut. It helps build a protective lining along the gastrointestinal tract, which keeps the gut sealed for healthy digestion. Also, collagen absorbs water in our intestines, which helps pass waste out of the body. Studies have found in digestive disorders, such as IBS (inflammatory bowel disease), patients have decreased serum concentrations in their body. [24] Serum is

the amino acid that glycine is derived from, so a decrease ultimately leads to insufficient collagen synthesis. In turn, the GI tract cannot be sealed, which leads to symptoms associated with various gastrointestinal disorders (i.e., IBS, leaky gut syndrome, Crohn's disease, acid reflux, ulcerative colitis).

6. Improves liver health.

Perhaps more important for gut health, collagen helps cleanse our liver, which regulates a host of metabolic functions, as well as immune response. In short, everything we consume passes through the liver — including unwanted toxins that enter our body (i.e., alcohol, nicotine, excess sugars, etc). [25]

Such toxins can lead to fatty acid buildup. In turn, this negatively impacts our metabolism and immune function. Research findings indicate that glycine in particular reduces alcohol-induced liver damage, because it elevates fatty acid transport. [26]

7. Protects the cardiovascular system.

The cardiovascular system is protected by a collagenous structure (cardiac skeleton), comprised of four bands of connective tissue (collagen). [27]

The presence of collagen throughout the cardiac skeleton is imperative for blood circulation. Its elasticity promotes vasodilation by enabling blood vessels to stretch open, whereas a loss of collagen hardens blood vessels, stripping the ability to flush fatty acids into the blood stream. In turn, this leads to plaque buildup, which can result in heart failure and atherosclerosis. [28]

8. Enhances body composition.

Glycine essentially sets off a chain reaction that boosts our energy, strength, and metabolism. First, the body uses glycine to convert glucose to energy that fuels muscle cells. So, not only do we get a boost of energy, but our muscles are fueled as well. Tying it all together, we see a boost in our overall metabolism, because muscle burns more calories than fat.

All of these points are demonstrated by a recent study that examined the anabolic response of resistance trainers who used collagen, compared to a placebo. Following a 12-week period, all participants experienced improved muscle strength and body composition, but the results were significantly greater for participants who used the collagen supplement. [29]

Types of Collagen

In 2000, 16 types of collagen had been identified. [30] Another decade of research brought the discovery of several molecular isoforms occurring within particular types, which revealed an increased diversity exists. In turn, 28 types of collagen have now been identified. [31] However, a vast majority of the human body is comprised of three types (i.e., type I, II, and III). We discuss each of these types below, along with type IV and V, as they also hold significance.

Type I collagen

Type I is by far the most abundant. According to some findings, type I accounts for over 90 percent of collagen in our body. [32] It's made up of eosinophilic fibers (often referred as collagen fibers) that form our skin, tendons, ligaments, organs, and bones. All in all, type I gives our skin elasticity so it doesn't tear, and it plays a major role in healing wounds.

Type II collagen

Type II is the main component of cartilage. It makes up about 50 percent of total cartilage and about 85 to 90 percent of articular cartilage, which is formed along the surface of our bones. Thus, biochemical breakdown of type II is linked to various joint diseases — with osteoarthritis being the most common. [33]

Type III collagen

Type III is comprised of reticular fibers, and it's a major component of the extracellular matrix throughout our internal organs and skin. It works in conjunction with type I collagen to make our skin elastic, yet firm. Type III is vital for the cardiovascular system — forming blood vessels and tissue in the heart. Deficiencies can lead to ruptured blood vessels, and in extreme cases, early death. [34]

Type IV collagen

Type IV forms the basal lamina (extracellular matrix secreted from epithelial cells that surround our muscles, organs, and fat); this lines most of our digestive organs and respiratory surfaces. The basal lamina essentially cushions the outer layer of skin. Type IV also forms connective tissue in the deepest layer to support the overall structure. [35]

Type V collagen

Type V is needed to make cell surfaces, hair strands, and connective tissue in the placenta (organ of the female body that lines the womb, regulates blood supply, provides oxygen and nutrients, and removes waste during pregnancy). Type V has also been shown to assist the immune response of the lungs. [36, 37]

Bioavailable Food Sources

(Plus Benefits of Each Particular Source)

As mentioned, collagen is the main structural protein in animal bodies. Therefore, bioavailable sources of collagen are derived from animals — including collagen supplements. (Hang on, vegans, don't fret.) There are plenty of vitamins and minerals that stimulate collagen production and/or prevent the breakdown of collagen; those will be discussed next. But first, let's take a look at some foods that provide a rich, bioavailable source of collagen.

Bovine (Cow or Beef) Collagen

Bovine collagen is found in the skin, bones, and muscles of cows. It mostly contains type I and type III, including a rich supply of amino acids glycine and proline. This makes bovine collagen especially helpful for building muscle, while it also helps the body produce more collagen.

Piscine (Fish) Collagen

Piscine collagen is derived from fish and primarily contains type I, along with amino acids glycine, proline and hydroxyproline. It has been shown to benefit the joints, bones, skin, hair, nails, blood vessels, vital organs, and digestive system. [38]

Egg Collagen

Egg collagen is found in the white, yolk, and egg shell membrane of chicken eggs. It contains types I, III, V, and X, but mostly type I (approximately 100 times more than the next most, type V). [39, 40] It's rich in glycine, proline, and hydroxyproline, among others (18 amino acids total) that benefit the health of connective tissue, joints, wound healing, and building muscle. [41] Plus, the egg shell membrane contains glucosamine sulfate, chondroitin sulfate, and hyaluronic acid; all of which are greatly beneficial for joints. [42]

Chicken Collagen

Chicken collagen is loaded with type II, which makes it particularly beneficial for building cartilage. It also helps build connective tissue in our bones, tendons, and skin. Plus, similar to egg collagen, chicken collagen contains glucosamine sulfate and chondroitin sulfate, so it provides an extra boost of joint support; both have been shown to provide anti-aging benefits as well. [43]

Vitamins & Minerals that Promote Healthy Collagen Production

The best way to prolong longevity is to incorporate a healthy dose of vitamins and minerals into our diet. Not only do some of the following nutrients promote healthy collagen production, most are paramount for collagen production, period.

Vitamin C

The two primary amino acids that form collagen, glycine and proline, are dependent on vitamin C as a cofactor in hydroxylation (biochemical process that forms hydroxyproline, which secures the secondary structure of collagen). This makes vitamin C imperative for collagen synthesis (particularly during the pre-collagen production phase). [44, 45] It's worth noting, in extreme cases, vitamin C deficiencies can result in scurvy (painful disease where lack of hydroxylation prevents formation of strong connective tissues). [46]

Vitamin C also serves as a powerful antioxidant. Antioxidants protect against the breakdown of collagen cells caused by free radicals (toxins) that occur in our air, food, and water supply. [47]

Vitamin E

Here's another dietary antioxidant essential for humans. Vitamin E is the most abundant antioxidant in the skin; consumption neutralizes free radicals that are damaging to collagen cells in the body. [48] It plays a vital role in protecting the skin from too much sun exposure. Some studies also indicate that topical application of vitamin E can help preserve healthy skin (i.e., ointment, skin cream, lotion, etc).

Zinc

Zinc is an essential trace mineral required for bone formation — largely due to its role as a cofactor for collagen synthesis. Zinc increases the osteogenic function of osteoblasts, which are cells that synthesize dense, cross-linked collagen proteins specialized to comprise the organic matrix of bone. [49] Furthermore, some findings indicate zinc

slows the breakdown rate of collagen in granulation tissues; it has even been shown to increase the rate of wound healing. [50, 51]

Copper

Copper is an essential trace mineral required for the formation of collagen fibrils. It serves as a cofactor to lysyl oxidase, a copper-dependent enzyme that completes the final step of collagen synthesis. In turn, the presence of copper ultimately dictates the formation of collagen in our body. [52]

Manganese

Manganese is an essential trace mineral required for the activation of prolylase, an enzyme that provides the amino acid, proline. [53] As noted earlier, proline is a principal component of the triple helix that collagen proteins are composed of (about 17% of the amino acid sequence).

Collagen Supplements

(Questions to Consider)

There are some important details that determine quality and effectiveness of a given collagen supplement. Let's discuss some important questions to consider when choosing a collagen supplement, as this will help us pinpoint the best quality.

Does the supplement contain hydrolyzed collagen?

In its native form, collagen molecules are too large for the body to absorb efficiently. Thus, a quality supplement should contain hydrolyzed collagen (also referred as collagen hydrolysate).

When hydrolyzed, collagen molecules have been reduced to small peptides for efficient absorption. Studies indicate more than 90% of hydrolyzed collagen is available in the blood stream within one hour of ingestion; thereafter, small peptides are transported to target tissues (i.e., skin, bones, cartilage), where they serve as building blocks to boost production of new collagen fibers. [54, 55, 56]

How much collagen does the supplement contain?

There are two types of amino acids: *essential* and *nonessential*. Essential amino acids are *not* biosynthesized in the body, which makes them *essential* for the human diet. Nonessential amino acids *are* biosynthesized in the body, which makes them *not essential* for the human diet.

The primary amino acid in collagen, glycine, is nonessential; it's biosynthesized in the body from serine. However, we need about 10 grams of glycine per day for collagen synthesis, but the metabolic capacity of glycine biosynthesis is about 3 grams per day. [57] This means we need about 7 grams of glycine per day from our diet, despite the misleading *nonessential* amino acid designation.

Does the formula contain vitamin C?

As mentioned, vitamin C is a cofactor for hydroxylation; meaning, vitamin C stimulates the production of procollagen (precursor to the formation of collagen). While it may not be necessary if our diet includes an adequate amount from natural food sources, choosing a collagen supplement that contains vitamin C will help to ensure optimal health benefits.

Check out the ingredients list – are there any added sugars, artificial flavors, or preservatives?

It somewhat defeats the purpose of consuming a collagen supplement when it contains ingredients that negatively impact our health, such as sugars, artificial flavors, or preservatives. High consumption of added sugars like fructose, for example, can lead to fat buildup around internal organs which causes a metabolic imbalance in the body. [58] On the flip side, a benefit to orally ingesting collagen is to build tissues that line our internal organs. In turn, this improves various bodily functions (i.e., cardiovascular, digestion, etc). Thus, in order to achieve maximum benefits of a collagen supplement, avoid any that use added sugars, artificial flavors, or preservatives.



Supplement Facts ^{V1}

Serving Size 1 Scoop (7.6 Grams)
Servings Per Container About 30

1 scoop contains	Amount Per Serving	% Daily Value
Calories	25	
Total Carbohydrate	0.8 g	<1%*
Dietary Fiber	0.5 g	2%*
Protein	5 g	10%*
Vitamin C (as Ascorbic Acid USP)	100 mg	111%*
Magnesium (as TRAACS® Magnesium Bisglycinate Chelate)	135 mg	32%
Sodium	50 mg	2%
Gelatine Hydrolysate (FORTIGEL®)	5.2 g	**
Tendoactive® (Standardized to contain 84% Mucopolysaccharides)	520 mg	**
Mobilee® (Standardized to contain 40 mg Hyaluronic Acid)	80 mg	**

* Percent Daily Values are based on a 2,000 calorie diet.

** Daily Value not established

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