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Vitamin K 101 — Essential Basics for Bone and Heart Health

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STORY AT-A-GLANCE

- Vitamin K is a fat-soluble vitamin necessary for blood clotting, bone health and cardiovascular function. It exists in two main forms: K1 (phylloquinone) found in green leafy vegetables, and K2 (menaquinones) found in animal products and fermented foods
- Vitamin K2 is essential for calcium metabolism, significantly impacting bone and cardiovascular health
- Vitamin K2 works synergistically with vitamin D to enhance bone health and reduce the risk of osteoporosis. This combination ensures that calcium is properly utilized and deposited in bones rather than accumulating in arteries
- Vitamin K2 is involved in activating proteins like osteocalcin and matrix Gla protein, which regulate calcium deposition in bones and arteries. This activation helps prevent arterial calcification and promotes bone strength
- The intake of vitamin K2 is often insufficient in Western diets, highlighting the need for increased consumption through dietary adjustments or supplementation to support bone and heart health

Vitamin K is a fat-soluble vitamin known for its essential role in blood clotting. However, its functions extend far beyond coagulation, encompassing processes that maintain bone integrity and cardiovascular health. There are two primary forms of vitamin K: K1 (phylloquinone), predominantly found in green leafy vegetables, and K2 (menaquinones), which is present in animal products and fermented foods.

While both forms are important, vitamin K2 has garnered significant attention for its unique ability to regulate calcium metabolism, directing this mineral to where it's needed most in your body. As such, it stands out for its pivotal role in enhancing bone density and preventing the calcification of arteries.

Without adequate vitamin K2, calcium accumulates in your arteries, increasing your risk of cardiovascular diseases. Conversely, insufficient calcium in your bones leads to osteoporosis, a condition characterized by weakened bones and an increased risk of fractures.

Despite its benefits, vitamin K2 is often under-consumed in Western diets, primarily due to the limited intake of fermented foods and certain animal products, combined with the overconsumption of processed foods. Certain medical conditions and medications also impair the absorption and metabolism of vitamin K2, increasing deficiency risks.

Optimize Your Health with the Right Forms of Vitamin K

When it comes to maintaining optimal health, vitamin K often doesn't get the spotlight it deserves. Understanding the different forms of vitamin K and their sources is essential to help you make informed decisions about your diet and supplementation.

Vegetable oils like soybean and canola are rich in vitamin K1, but relying on these oils is a dangerous choice for your overall energy and metabolic health. High intake of vegetable oils, which contain linoleic acid (LA), leads to impairments in mitochondrial energy production, which is essential for cellular function.

While conventional nutrition guidance encourages getting vitamin K1 from these oils, eliminating them from your diet is essential for optimal health. Therefore, diversifying your vitamin K intake from other sources is necessary.

Vitamin K2 offers additional health benefits that K1 does not. MK-7, a form of K2, is especially potent due to its longer half-life in your body, ensuring more consistent levels that support bone density and cardiovascular health. Unlike K1, which is quickly utilized

by your liver, K2 travels to your bones and arteries, where it activates proteins that regulate calcium deposition.

This dual action helps prevent osteoporosis and reduces your risk of arterial calcification, a key factor in heart disease.

As for dosage, the European Food Safety Authority recommends an intake of 1 microgram per kilogram of body weight per day of total vitamin K, for both children and adults, including pregnant women.[1] However, many experts suggest that higher doses of K2 may be beneficial, especially for those at risk of bone loss or cardiovascular issues.

Common supplementation ranges from 100 to 200 micrograms of MK-7 daily, which has been shown in studies to effectively improve bone mineral density (BMD) and reduce arterial stiffness without adverse effects. It's important to note that while natural vitamin K supplements are generally safe, synthetic forms like vitamin K3 (menadione) are toxic in high doses and should be avoided.

Incorporating a balanced intake of both K1 and K2 through diet and, if necessary, supplementation supports your body's needs without the drawbacks associated with excess vegetable oil consumption. Focus on leafy greens for K1 and fermented foods or high-quality supplements for K2 to harness the full spectrum of vitamin K's health benefits.

Understanding Vitamin K Deficiency

Vitamin K deficiency manifests through symptoms primarily related to impaired blood clotting. You might notice spontaneous cutaneous purpura, which are purple spots on your skin caused by small blood vessels leaking under the surface. Epistaxis, or frequent nosebleeds, is another common indicator.

Additionally, you could experience gastrointestinal bleeding, genitourinary bleeding (i.e., blood in the urine, vaginal bleeding or bleeding from the urethra), gingival bleeding (bleeding gums) or other unexplained bleeding episodes. In addition to poor dietary

intake, certain health conditions increase your risk of vitamin K deficiency by impeding your body's ability to absorb or use vitamin K.

Liver diseases, such as cirrhosis or hepatitis, reduce your liver's capacity to store and process vitamin K. Cholestasis, a condition where bile flow is reduced or blocked, also hinders vitamin K absorption since it's a fat-soluble vitamin. Additionally, conditions like cystic fibrosis, alcoholism, and malabsorption disorders (including inflammatory bowel disease) also compromise your vitamin K levels.[2]

Weight loss surgeries that alter the digestive system also affect nutrient absorption, including vitamin K. So, if you've undergone such procedures, monitoring your vitamin K intake becomes essential. Certain drugs also interfere with vitamin K metabolism or absorption.

Coumarin-based anticoagulants, commonly prescribed to prevent blood clots, directly inhibit vitamin K's role in blood clotting. Antibiotics like rifampicin disrupt gut bacteria that synthesize vitamin K2, further lowering your levels. Further, orlistat, a weight-loss medication, reduces fat absorption, which inadvertently decreases vitamin K absorption since it's fat-soluble.[3]

Vitamin K2 for Bone Health, Heart Disease and Cancer

A comprehensive review published in Food Science & Nutrition explored the extensive benefits of vitamin K2, particularly focusing on its impact on bone health, **cardiovascular protection** and cancer.[4] The research looked at how different forms of vitamin K2 contribute to these health outcomes and sought to understand the underlying mechanisms.[5]

The researchers found that higher intake of vitamin K2 significantly lowers the risk of developing osteoporosis. Additionally, participants who consumed more vitamin K2 had a reduced incidence of heart disease, highlighting the nutrient's protective role in cardiovascular health.[6]

One of the standout findings was the relationship between vitamin K2 and cancer. The study highlighted that vitamin K2 has positive effects on the prevention and treatment of malignant tumors, offering a promising avenue for future cancer prevention strategies.[7]

Furthermore, the research explored the synergistic relationship between vitamin K2 and vitamin D. When these two vitamins are consumed together, their combined effect on bone health is more pronounced than when either is taken alone. This synergy enhances your body's ability to maintain strong bones by ensuring that calcium is properly used and deposited where it's needed most.[8]

If you're supplementing with vitamin D, it's especially important to balance it with vitamin K2 and magnesium, as they work together to prevent inappropriate calcification.

Different Forms of Vitamin K2

The featured study also highlighted three different forms of vitamin K2 — MK-4, MK-7 and MK-9. Of these, MK-4 had the highest bioactivity, meaning it's particularly effective at activating proteins that regulate calcium. MK-7, meanwhile, was noted for its superior bioavailability and longer half-life, allowing it to remain active in your body for extended periods.[9] Natto, a traditional Japanese fermented soybean dish, is the richest source of MK-7.[10]

While the majority of vitamin K1 is stored in your liver, MK-4 is the primary form of vitamin K2 found in human tissues. This distinction indicates that different forms of vitamin K have specific roles and are stored differently within your body.[11]

Vitamin K2, as mentioned, is particularly involved in the maintenance of calcium homeostasis. Calcium homeostasis refers to the regulation of calcium levels in various biological pathways, ensuring that calcium is available where needed for functions like bone formation while preventing its accumulation in soft tissues and blood vessels.[12]

By directing calcium to your bones and teeth, vitamin K2 ensures that it's used effectively, enhancing overall skeletal and cardiovascular health.[13] Vitamin K2 achieves this by activating proteins such as osteocalcin and matrix GLA-protein (MGP).

Osteocalcin plays a pivotal role in binding calcium to your bone matrix, thereby strengthening bones.

Meanwhile, MGP prevents the deposition of calcium in blood vessel walls, reducing the risk of vascular calcification and subsequent cardiovascular diseases.[14] Additionally, vitamin K2 modulates the activity of osteoblasts and osteoclasts, the cells responsible for bone formation and resorption, respectively.

By downregulating the activation of nuclear factor-κB, a protein complex involved in inflammatory responses, vitamin K2 helps maintain a balanced activity of these bone cells, promoting bone health and preventing excessive bone loss.[15]

The study also touched upon the neuroprotective effects of vitamin K2. Specifically, MK-7 was shown to protect brain cells from apoptosis, or programmed cell death, induced by hypoxic conditions. This finding opens up therapeutic applications for vitamin K2 in treating neurodegenerative diseases and other mitochondrial-associated disorders.[16]

Vitamin K2's Role in Mitochondrial Energy Production

Vitamin K2 exhibits a broad spectrum of biological activities, influencing nearly all major body systems, including mitochondrial energy release. Mitochondria are responsible for producing adenosine triphosphate (ATP) through the electron transport chain.

Vitamin K2, which is structurally similar to coenzyme Q10 (CoQ10), plays a role in mitochondrial energy metabolism.[17] Studies have shown that vitamin K2 acts as a mitochondrial electron carrier, rescuing mitochondrial dysfunction caused by Pink1 protein deficiency, which is linked to Parkinson's disease.[18] Vitamin K2 facilitates electron transport within mitochondria, thereby enhancing ATP production and improving cellular energy levels.

However, conflicting evidence exists regarding vitamin K2's role in mammalian mitochondrial function. While some studies suggest beneficial effects on mitochondrial respiration and energy release, others indicate that vitamin K2 does not substitute for CoQ10 in restoring electron flow or ATP synthesis in CoQ10-deficient cells. This

discrepancy highlights the need for further research to uncover vitamin K2's exact role in mitochondrial energy metabolism across different species.

Vitamin K for Optimal Health During Menopause

Menopause induces significant hormonal and physiological changes, contributing to conditions such as osteoporosis, osteopenia and increased vascular calcification. Vitamin K2 has been extensively studied for its beneficial effects in mitigating these menopausal effects.

Clinical trials have demonstrated that vitamin K2 supplementation, particularly in the forms of menaquinone-4 (MK-4) and MK-7, improves bone mineral density (BMD) and bone mineral content (BMC) in postmenopausal women.[19]

For instance, a meta-analysis of randomized controlled trials revealed that daily intake of MK-4 for three years enhanced hip bone geometry and strength by increasing BMC without significantly altering BMD.[20] Additionally, MK-7 supplementation has shown to synergize with calcium and vitamin D3, further supporting bone health by increasing osteocalcin carboxylation and reducing bone resorption markers.[21]

Vitamin K Has Neuroprotective Properties and Protects Your Liver

Beyond its menopausal benefits, vitamin K2 demonstrates significant hepatoprotective and neuroprotective properties, contributing to liver regeneration and cognitive health. In liver health, vitamin K2 supplementation has been shown to enhance liver regeneration following liver surgery in rat models.[22]

Additionally, vitamin K2 exhibits cytotoxic effects on liver cancer cells by inducing cell cycle arrest and apoptosis through multiple signaling pathways, including the suppression of NF-κB and MAPK activities.[23]

Further, vitamin K supports cognitive function and neuronal health. Studies in rodent models have linked adequate vitamin K2 levels with improved cognitive performance and reduced neuroinflammation. Vitamin K2 activates the Gas6/Axl/Akt signaling pathway, which inhibits apoptosis and enhances neuronal survival.[24]

Moreover, vitamin K2 protects neural cells from oxidative stress and amyloid-beta toxicity, factors implicated in Alzheimer's disease.[25] These neuroprotective mechanisms underscore vitamin K2's role in preventing and managing neurodegenerative diseases.

Vitamin K for the Treatment of COVID-19

Emerging research also suggests that vitamin K2 may play a role in mitigating the severity of COVID-19. COVID-19 is associated with coagulopathies and excessive inflammation, conditions where vitamin K2's regulatory functions on coagulation and inflammation are likely beneficial. Observational studies have indicated that vitamin K deficiency is linked to increased disease severity and mortality in COVID-19 patients.[26]

Vitamin K2 may help in activating vitamin K-dependent proteins like MGP and Protein S, which are key for preventing vascular calcification and thrombosis, common complications in severe COVID-19 cases.[27] Furthermore, vitamin K2's anti-inflammatory properties help in reducing the cytokine storm associated with acute COVID-19, thereby improving patient outcomes.

Vitamin K for Parathyroid Disorders and Cerebral Palsy

A review published in the journal Nutrients also highlighted the impact of vitamin K2 on multiple health conditions. Beyond osteoporosis and cardiovascular disease, studies have shown that adequate vitamin K2 intake positively influences parathyroid disorders, cerebral palsy and sperm motility, suggesting its broad therapeutic potential.[28] These findings emphasize the need for optimizing vitamin K2 in the diet to maintain overall health.

Parathyroid disorders, particularly hyperparathyroidism, involve the excessive secretion of parathyroid hormone (PTH), leading to elevated serum calcium levels (hypercalcemia) and subsequent bone resorption. Vitamin K2 plays a role in calcium metabolism, which directly impacts parathyroid function.

Further, researchers demonstrated that vitamin K2 supplementation in hemodialysis patients, who often suffer from secondary hyperparathyroidism, resulted in increased levels of carboxylated osteocalcin without significantly altering PTH, calcium or phosphate levels. This suggests that vitamin K2 mitigates the adverse effects of elevated PTH by enhancing bone mineralization and reducing calcium loss from bones.[29]

Moreover, vitamin K2's activation of MGP inhibits vascular calcification, a common complication in hyperparathyroid patients. By preventing the inappropriate deposition of calcium in blood vessels, vitamin K2 indirectly supports parathyroid health by maintaining balanced calcium distribution within the body.

Although vitamin K2 does not directly lower PTH levels, its role in optimizing calcium metabolism offers a complementary approach to managing parathyroid disorders alongside conventional treatments.

Cerebral palsy (CP) is a group of neurological disorders that affect movement, muscle tone and posture, often resulting in decreased BMD and increased fracture risk. Osteoporosis is prevalent among individuals with CP due to reduced mobility and subsequent bone resorption. According to researchers, vitamin K2 supplementation could play a significant role in improving bone health in CP patients.[30]

Additionally, vitamin K2's role in regulating bone remodeling also supports overall skeletal integrity in individuals with CP. While direct studies on vitamin K2 and CP are limited, the existing evidence on its impact on bone health provides a compelling rationale for its inclusion in therapeutic regimens aimed at mitigating osteoporosis in CP patients.

Vitamin K Enhances Sperm Motility

Sperm motility is a critical factor in male fertility, governed by the functionality of calcium channels and the integrity of spermatozoa. Vitamin K2 has been implicated in enhancing sperm motility through its involvement in calcium metabolism and the maturation of sperm cells.

Researchers investigated the effects of vitamin K2 on sperm maturation, revealing that K2-dependent proteins are highly expressed in the epididymis, the site of sperm maturation. Warfarin-induced inhibition of vitamin K2 activity resulted in decreased sperm count and motility, underscoring the vitamin's essential role in maintaining sperm health.[31]

Vitamin K-Dependent Proteins in Biomineralization

Research published in the International Journal of Molecular Medicine focused on the role of vitamin K in the activation of proteins essential for bone and vascular health, emphasizing its involvement in biomineralization processes.[32] The research underscored the importance of vitamin K in the post-translational modification of vitamin K-dependent proteins (VKDPs), which are primarily involved in coagulation and calcification.[33]

There are 17 identified VKDPs, which include osteocalcin and MGP. Osteocalcin, synthesized by osteoblasts, requires vitamin K for carboxylation, converting glutamic acid residues to gamma-carboxyglutamate (Gla) residues.[34] This conversion enhances osteocalcin's calcium-binding capacity, thereby reinforcing bone structure.[35]

Without sufficient vitamin K, osteocalcin remains undercarboxylated, reducing its effectiveness in supporting bone health.[36] Similarly, MGP gains a higher affinity for calcium upon carboxylation, which prevents its deposition in arterial walls, thereby lowering the risk of cardiovascular diseases like atherosclerosis.[37]

The study highlights that inadequate vitamin K levels impair MGP's ability to prevent calcium accumulation, leading to arterial calcification and increased cardiovascular risk.[38] Additionally, the study clarified the distinct functions of vitamin K1 and K2, with

vitamin K1 playing a major role in coagulation, while vitamin K2 is more prevalent in tissues other than the liver.[39]

The review also addressed the absorption and transport pathways of vitamin K1 and K2, noting that vitamin K1 is absorbed with triglyceride-rich lipoproteins, while vitamin K2 is primarily transported by low-density lipoproteins (LDL).[40] This difference in transport mechanisms influences the distribution and bioavailability of each vitamin K form in your body.[41]

The Interplay Between Lipids and Vitamin K Metabolism

A review published in Nutrition & Metabolism further explored the intricate relationship between lipids and vitamin K metabolism, specifically focusing on how lipid levels affect the absorption and transportation of vitamin K within the body.[42]

The paper reviewed data from individuals with varying lipid profiles and those undergoing treatment with cholesterol-lowering medications such as statins. The findings revealed that vitamin K absorption and transportation are significantly influenced by the presence of lipids in the digestive system, underscoring the importance of adequate dietary fat intake for the optimal utilization of vitamin K.[43]

Vitamin K shares transporters with cholesterol, meaning that both substances compete for the same pathways within your body. This competition impacts the efficiency with which vitamin K is distributed to essential tissues.

The study also explored the role of lipoproteins, which are particles that transport fats, including cholesterol and triglycerides, through the bloodstream. It was found that low-density lipoproteins (LDL), often referred to as "bad cholesterol," play an important role in transporting vitamin K2 to tissues such as bones and blood vessels.[44]

Furthermore, statins inhibit the mevalonate pathway, a biochemical pathway that's involved not only in cholesterol synthesis but also in the production of vitamin K2 isoforms like MK-4. By blocking this pathway, statins reduce the synthesis of vitamin K2, compromising its protective roles in your body.[45]

For this reason, individuals taking statins benefit from vitamin K2 supplementation to counteract this adverse effect. Moreover, the interplay between lipids and vitamin K metabolism extends to dietary recommendations. Diets that include healthy fats, such as butter and coconut oil, enhance the absorption of vitamin K, improving its bioavailability and efficacy in your body.

Remember, vitamin K is a lipophilic vitamin, meaning it dissolves in fats and is transported through your body via lipid-based carriers. This characteristic necessitates the presence of dietary fats for effective absorption in your small intestine. Once absorbed, vitamin K is packaged into lipoproteins for distribution to various tissues. The efficiency of this process is directly tied to your body's lipid metabolism, illustrating the interconnectedness of these two important components.[46]

Vitamin K and Its Impact on Other Nutrients

Understanding how vitamin K interacts with other nutrients is also helpful for optimizing your health and ensuring that you're getting the most out of your dietary intake and supplements. Insights from pharmacokinetic studies highlight the intricate relationships between vitamin K and other vitamins, particularly those that deplete or compete for its absorption and metabolism.[47]

One of the most significant interactions involves vitamin K and vitamin E, a powerful antioxidant essential for protecting your cells from oxidative stress. Both are fat-soluble vitamins that share similar metabolic pathways, leading to competition that affects their respective levels in your body. Studies have shown that the presence of vitamin E, as well as other fat-soluble vitamins, significantly reduces the absorption of vitamin K, with absorption rates dropping by 34% to 58%.[48]

The competition arises because vitamins E and K vie for the same enzymes involved in their metabolism. Specifically, both vitamins compete for cytochrome P450 (CYP450) enzymes, which are responsible for hydroxylating the side chains of these vitamins.[49] This competition leads to increased metabolism and excretion of vitamin K when vitamin E levels are high, diminishing vitamin K's effectiveness in your body.

So, if you're supplementing with vitamin E, it's important to monitor your vitamin K intake to prevent deficiencies. For instance, individuals taking high doses of vitamin E supplements might inadvertently reduce their vitamin K levels, increasing the risk of bleeding disorders and bone weakening. To maintain a healthy balance, consider spacing out the intake of these vitamins or consulting with a health care professional to adjust dosages appropriately.

How to Optimize Your Vitamin K2 Levels

Vitamin K2 serves as the body's master regulator for calcium distribution, ensuring this essential mineral is directed appropriately to support bone strength and prevent arterial calcification. By optimizing your vitamin K2 levels, you enhance bone integrity while safeguarding your cardiovascular health, providing a dual advantage for long-term well-being.

Determining whether you're getting enough vitamin K is challenging because there's currently no simple test available to measure vitamin K2 levels directly. Instead, vitamin K2 status is assessed indirectly by evaluating levels of undercarboxylated osteocalcin, a marker that indicates vitamin K2 activity in your body. However, this type of testing is not yet available for commercial use.

Generally, individuals with osteoporosis, heart disease or diabetes are likely to have a vitamin K2 deficiency. If you're taking statin medications, which are known to reduce vitamin K2 levels, you're also at risk of deficiency. Moreover, it's believed that most people do not get enough vitamin K2 and could benefit from increasing their intake. To boost your levels:

1. **Prioritize vitamin K2-rich foods —** Incorporate natto (fermented soybeans) and other vegetables fermented with vitamin K2-producing bacteria into your daily diet. These options provide the MK-7 form of K2, which remains active in your body for extended periods.

Certain cheeses, including Brie, Munster and Gouda, are also particularly rich in vitamin K2. Grass fed organic animal products, including egg yolks, liver, butter, tallow and dairy products, are also good sources of vitamin K2.

2. **Align K2 intake with healthy fats —** As vitamin K2 is fat-soluble, it should be consumed alongside healthy fats such as grass fed butter or tallow to enhance absorption. This practice ensures that your body effectively utilizes this nutrient for maintaining both bone density and cardiovascular health.

3. **Harmonize K2 with complementary nutrients —** Vitamin K2 works synergistically with vitamins D3, calcium and magnesium. When supplementing with vitamin D3, also include K2 to prevent calcium from depositing in your arteries. This balanced nutrient approach promotes bone strength while protecting your cardiovascular system.

4. **Opt for premium supplement sources —** If you choose to use supplements, select those containing the MK-7 form of K2. The recommended daily intake is 150 to 200 micrograms for most adults. For optimal absorption, take supplements with meals that include healthy fats.

Egg Yolks Are Your Best Source of Vitamin K2 as MK-4

Of the foods highlighted above, egg yolks are among the highest dietary sources of MK-4, a vital form of vitamin K2 that plays a crucial role in bone health, cardiovascular function and calcium regulation. Including egg yolks in your diet can significantly contribute to your MK-4 intake, supporting various aspects of your health.

You just need to be careful about your egg sources as most commercial egg sources — even free-range organic — have high PUFA levels as they are fed grains like soy and corn. Ideally, chickens should be fed rice, barley and split peas. I personally eat six egg yolks a day from chickens who are fed this and have 80% less linoleic acid than regular chickens.

Below is a comprehensive overview of egg yolks as a top source of MK-4, along with additional dietary sources and considerations.

Summary Table: Nutrient Comparison in Egg Yolks vs. Other Sources

Nutrient	Egg Yolk Content (per large yolk)	Other Top Sources
MK-4 (Vitamin K2)	~15 mcg	Chicken liver (~13 mcg/100g), Beef liver (~11 mcg/100g), Butter (~15 mcg/100g)
Choline	~147 mg	Beef liver (~418 mg/100g), Soybeans (~116 mg/100g), Salmon (~56 mg/100g)
Vitamin D	~37 IU (0.925 mcg)	Fatty fish (~400-600 IU/100g), Fortified dairy (~100 IU per serving)
Vitamin A	~245 IU	Beef liver (~6,582 IU/100g), Sweet potatoes (~19,218 IU/100g)
Selenium	~15.4 mcg	Brazil nuts (~544 mcg/100g), Tuna (~108 mcg/100g)
Vitamin B12	~0.6 mcg	Clams (~84 mcg/100g), Beef liver (~70 mcg/100g)
Riboflavin (B2)	~0.2 mg	Beef liver (~4.5 mg/100g), Almonds (~1.1 mg/100g)
Folate (B9)	~24 mcg	Beef liver (~145 mcg/100g), Spinach (~194 mcg/100g)
Biotin (B7)	~10 mcg	Liver (~100 mcg/100g), Almonds (~60 mcg/100g)

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