Vitamin D has much to offer athletes, but some of the most useful information has not been adequately disseminated and there is much confusion about its safety. Also, questions still remain as to how much is needed and how much is too much.

Sources of vitamin D include UVB rays from the sun and sunlamps, D2 and D3 in capsule form, and some foods which naturally have small amounts or are fortified with D. The most well-known food source is cod liver oil but this can be problematic due to its high vitamin A content which can interfere with vitamin D efficacy and cause risk of illness at high levels. Foods considered as vitamin D “super foods,” although the amount of vitamin D may still be negligible compared to recommended doses, are salmon, mackerel, and mushrooms exposed to ultraviolet light. Additional food sources include canned tuna (in water), canned sardines (in oil), milk, yogurt, egg yolks, and cheese.

UVB rays are converted by your skin to pre-vitamin D3 which, over a span of a few days, are converted to vitamin D3. This is also known as cholecalciferol. Vitamin D3 then circulates in the blood and is transported to the liver, where it is converted to 25-hydroxy-vitamin D [25(OH)D]. This is often called a prehormone as it eventually gets converted in the kidneys and in many tissues to the hormone 1,25-dihydroxy-vitamin D (also called calcitriol, or activated vitamin D). It is this form that enters cells and attaches to vitamin D receptors (VDRs) located in the nucleus of cells. This, of course, is dependent on exposure to UVB rays which is difficult during winter months and it is often filtered or blocked with sun protective lotions during summer months.

Activated Vitamin D: A Potent Steroid Hormone

John J. Cannell, MD, whom I reference numerous times in this article, has been at the frontier of vitamin D research and is the executive director of the Vitamin D Council (1). He refers to calcitriol as a “potent steroid hormone,” not to be confused with anabolic steroid hormones that are banned from athletic competition by the World Anti-Doping Agency (2). Calcitriol works by affecting the genome, turning genes on and off in response to a wide range of diseases and assisting with the body’s “innate immune response.”

VDRs have been observed in many of the body’s organs as well as in muscles, nerve cells, blood cells, skin, and even in immune-system cells circulating in the blood; hence, showing the importance of vitamin D throughout the body.

Prioritized Use

In his book, Athlete’s Edge: Faster Quicker Stronger with Vitamin D, Dr. Cannell describes prioritized use of vitamin D in the body. His description breaks it down into descriptions of “pools” where the 25(OH)D in the blood first fills the body’s pool in the kidneys for regulating calcium. This is the highest priority and without this need met, our bodies would fail. After minimal calcium needs for the kidneys are met, or the pool is filled, the 25(OH) D then becomes available for filling hundreds of other pools in the body (2). Having read more than a thousand research reports on vitamin D, I have observed that positive results for some diseases are not seen until the blood serum level of 25(OH)D reaches 70 ng/mL and higher. For peak athletic performance, Cannell estimates that the blood serum level needs to reach approximately 50 ng/mL (2).

How Much is Too Much?

There is considerable controversy over how high blood serum levels of vitamin D can become before adverse effects begin to occur. On November 30, 2010, a panel of the Food and Nutrition Board (FNB) of the Institute of Medicine (IOM) provided new dietary reference intakes (DRI) for vitamin D and calcium, following a review of the latest information on health outcomes associated with their intake. The IOM panel set the upper limit (UL) on intake at 4,000 IU/day stating that “once intakes of vitamin D surpass 4,000 IU per day, the risk for harm begins to increase.” Looking at their full report (1,132 pp.) provides a very different picture. The report cites a two-week study of rats showing “the results indicated that frank toxicity was achieved at...50,000 IU/kg body weight, producing a blood 250HD level of 1,607 nmol/L [642.8 ng/mL], while calcitriol levels were markedly reduced” (3). On the same page, the report summarizes the evidence for toxicity: “…the literature contains evidence that a range of vitamin D supplements from 800 to 300,000 IU/day have been used for periods ranging from months to years. Doses below 10,000 IU/day are not usually associated with toxicity, whereas doses equal to or above 50,000 IU/day for several weeks or months are frequently associated with toxic side effects including documented hypercalcemia” (3).

In East Germany between the 1940s and 1960s, children would routinely get six doses of 600,000 IU of vitamin D between 3 months and 18 months old, for a total of 3,600,000 IU at age 18 months. A study called “Intermittent High Dose Vitamin D During Infancy” researched the safety of this policy by studying 43 infants. Blood samples were collected before the quarterly dose and then two weeks after the dose to obtain 25(OH) D, 1,25(OH)2D, and calcium levels. It was found there was no evidence of cumulative increases of 25(OH)D. Thirty-four percent of the children experienced at least one episode of hypercalcemia but remained healthy, and repeated inquiries failed to identify clinical vitamin D toxicity as a result of the prophylactic program (4).

Still, there is controversy surrounding vitamin D dosing with many stating that “too much vitamin D is bad for you.” Some of that concern comes from all-cause mortality studies that show a rise in mortality at very low 25(OH)D levels. A slight increase in mortality has been seen after reaching only about 20 ng/mL to 32 ng/mL. It is difficult to judge this, however, because there are no known ways in the literature to account for this mortality rate. At these relatively low levels, benefits from D3 are just starting to be seen.

While 5,000 IU/day of D3 is widely recommended (and endorsed by the Vitamin D Council), athletes can take up to 10,000 IU/day without worrying about adverse effects. The IOM panel set the No Observed Adverse Effects Level (NOAEL) at 10,000 IU/day (3). In addition, Cannell has written, “…if there are any studies showing 20,000 IU/day is unsafe, I would like to see them” (5).
The performance benefit that athletes can achieve from taking D3 depends on their blood serum level starting point. Very deficient athletes (below 20 ng/mL) may see dramatic improvement quickly. The higher the starting point, the less potential there is for improvement.

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Vitamin D epidemiological studies are difficult to draw conclusions from because there are many confounding elements; however, the sheer number of studies reporting positive results provide reasonable confidence that it can safely improve health status. Often, reports showing negative results use doses and/or 25(OH)D levels that are far too low to achieve recordable positive results. Vitamin D researcher Dr. Cedric Garland, of the Moores Cancer Center of the University of Southern California, San Diego, says, “We are moving into a new era of using vitamin D in doses no less that 4,000 IU/day for people aged nine years and older... Studies using less than 4,000 IU/day are on the verge of obsolescence” (6).

Defining Deficiency

Cannell identifies 50 ng/mL as the minimum needed to reach peak athletic performance; therefore, for the objective of this paper, we'll define deficiency as occurring below that level. He suggests an intake of 5,000 IU/day of D3 as the minimum for most adults with higher doses for those who need more to reach 50 ng/mL. He also suggests higher blood serum levels for individuals suffering from certain diseases, especially when deficiency has been identified (7). A Task Force of the Endocrine Society issued clinical guidelines for vitamin D in which they suggest sufficiency of Vitamin D as a 25(OH)D of 30–100 ng/mL (8). It is also recommended by some to supplement vitamin D intake with magnesium and vitamin K to help with its efficacy.

Interestingly, many epidemiological studies show that individuals are healthier during warm months. They also show that latitudinal location can impact health with those living closer to the equator having a lower risk of cancer and other diseases.

The Sun as a Source of D

Athletic performance studies show that athletes perform better when they can get more sun. Of course we lose that advantage the more we shield ourselves from the sun's rays. The question then arises, how much sun exposure is safe? Too much and we may be at risk for skin cancer while not enough can put us at risk for internal cancers. The most common forms of skin cancer, squamous cell and basal cell carcinomas, are often easily taken care of, but internal cancers can be more difficult to treat and have the threat of spreading (8).

Because UVB rays are the ones responsible for providing vitamin D, we need to get sun exposure at the time when those rays are available (when our shadow is shorter than we are tall). That leaves out the winter, and much of the spring and fall. Also, during the day, the sun needs to be above 50 degrees from the horizon so that exempts much of the morning and afternoon (depending on the season). You can see which hours are best by location and date using the Navy’s Azimuth calculator at http://aa.usno.navy.mil/data/docs/AzAlt.php.

It is recommended you receive about 15 minutes of exposure with minimal clothing to get 10,000 to 25,000 IU of D3, and there is general consensus that it is nearly impossible to overdo on D3 through sun exposure. The darker your skin, the more time you need. Most African Americans get so little D3 from the sun that they need to depend on supplements. Very light-skinned individuals who burn very quickly may also need to depend solely on D3 supplements to avoid the harm caused by sunburn (9).

Dr. Cannell makes a strong case in his book arguing that the very strong UVB rays at the latitude and altitude of Mexico City helped our athletes dominate at the 1968 Olympic Games. Our African American athletes arrived early to adjust to the altitude but unknowingly increased the duration of their exposure to UVB rays and, most likely, benefited from that exposure. It is estimated that dark-skinned individuals need 10 times the exposure that fair-skinned individuals need in order to achieve the same benefits. It may be just a theory, but some records accomplished by these athletes in Mexico City held for decades (2). It does make you think.

The performance benefit that athletes can achieve from taking D3 depends on their blood serum level starting point. Very deficient athletes (below 20 ng/mL) may see dramatic improvement quickly. The higher the starting point, the less potential there is for improvement. Therefore, it is valuable to know the blood serum level as a guide for what is needed. Some people do not absorb D3 well and can be deficient even with high intake. It is also important to recognize that some studies stating benefits to a specific population may need further investigation. For example, many studies showing that D3 can benefit athletes were actually performed on elderly and/or vitamin D deficient populations.

Placebo Controlled Studies

A double-blind, placebo-controlled study performed at the Tufts Medical Center in Boston showed promising effects of vitamin D supplementation. Participants included 21 women aged ≥65 with 25(OH)D levels of 9 to 24 ng/mL. The treated group was given 4,000 IU/day of D3 for four months. The untreated group received the placebo. At the end of this time period, there was a 30% increase in intramyonuclear VDR concentration and, using before and after muscle biopsies, a 10% increase in muscle fiber size of the treated group. There was no change in the placebo group. The most prominent increase in muscle fibers was in type I (fast-twitch) versus type I (slow-twitch) fibers (10).

In a controlled four-month study in the UK looking at the effects of 2,000 IU/day of D3 supplementation on elite classical ballet dancers training indoors during winter months, the treated group of 17 had an increase of 18.7% in isometric strength and 7.1% in vertical jump. The control group had no change in isometric strength and a 2% decline in vertical jump. In addition, the treated group sustained significantly fewer injuries during the four-month period (11).

A placebo-controlled trial performed to assess the vitamin D concentration of 61 non-vitamin D supplemented UK-based athletes and 30 age-matched healthy non-athletes also examined the effects of 5000 IU/day of D3 supplements for eight weeks on musculoskeletal performance. Results showed that 62% of the athletes and 73% of the controls had blood serum of 25(OH)D of less than 20 ng/mL. After eight weeks, the treated group had an increase of 25(OH)D to 41 ± 10 while the controls had no change. The authors report there was a significant improvement in 10m sprint time and in vertical jump by the treated group and no change by the controls (12).

In a double-blind, randomized, placebo-controlled study, 23 healthy, overweight, and obese adults were divided into two groups, vitamin D and placebo, with each group consisting of both males and females. Both groups completed 12 weeks of resistance training. Peak power was significantly increased at four weeks in the vitamin continued on page 7
D group only. This group also experienced, exclusively, a reduction in waist-to-hip ratio (13).

Studies Using Sunlamps
Cannell spent considerable time reviewing East German and Soviet articles covering the 1930s to 1950s and found studies on UV radiation exposure that seem to be unknown in the US. In one report of a 1938 Russian study, scientists used UV irradiation treatments on four college students and compared this with four untreated college students. Using before and after testing with the measure being the 100m dash, the treated group reduced their times from an average of 13.63 to 12.62 seconds while the untreated group reduced their times from an average of 13.51 to 13.28 seconds (14).

In 1940, two German researchers found that UV radiation improved the ability of muscles to metabolize lactic acid. They theorized that it was the vitamin D production that re-synthesized the lactic acid to glycogen. This enabled more intense exercise to continue for a longer duration (15).

In 1945, R.M. Allen and T.K. Cureton were the first Americans to test the findings of UV's effect on lactic acid synthesis. They treated one group of 11 males who were undergoing training in an indoor physical education class with UV radiation. Subjects received UV radiation while nude for up to two minutes per session, three times per week for 10 weeks in late fall and winter. There was a group of 10 matched controls. At the end of this period, the treated group had a 19% gain in endurance fitness versus 1.5% improvement in the controls. The control group also reported contracting twice as many viral respiratory infections as the treated group (16).

The protection from viral respiratory infections that UV radiation appeared to provide is known to result from the increased calcitriol raising levels of antimicrobial peptides. There are thousands of epidemiological studies showing a strong correlation of high 25(OH)D with low incidence of many diseases including cancer and heart disease. This has motivated many research institutes to perform randomized, controlled trials to see if increasing 25(OH)D causes decreased incidence of diseases. The effect of D3 has been seen to be dose-dependent; therefore, the studies using correct dosage of D3 are showing it to be effective. Athletes can benefit by this protection by gaining more time for training and being more available to compete.

In the early 1950s, reports Cannell, exercise physiologists at the German Sport University in Cologne exposed all athletes on both sides of their bodies with sunlamp irradiation for up to 10 minutes twice per week for six weeks. They reported a “convincing effect” on performance and a 50% reduction in sports injuries. The beneficiaries were swimmers and soccer, handball, hockey, and tennis players. They also exposed boxers and most of the track and field athletes. Interestingly, their results also showed that once athletes reached peak performance, further radiation impaired performance (17).

Cannell reports on many more supporting studies performed in East Germany. The results of these studies confirmed the ability of UV radiation to enhance performance including improved endurance and reaction time and lowered resting pulse and basal metabolic rate. These findings are similar to the benefits shown for vitamin D supplementation (2).

Conclusion
Controlled studies of physical performance in both males and females show benefit from increasing blood serum levels of 25(OH)D using sunlamps or oral intake of vitamin D. Improved performance of both strength and endurance have been seen. Other benefits shown are increased muscle fiber size, fewer injuries, better lactic acid metabolism, and reduced incidence of upper respiratory illness. Doses as high as 10,000 IU/day of D3 can be used safely based on a report from the Institute of Medicine (3).

Recommendation
To achieve peak performance, athletes should have blood serum levels of 25(OH)D of at least 5,000 ng/mL. Each athlete should find his/her most beneficial intake level from the sun, sunlamps, and capsules of vitamin D3 to reach this blood serum level with knowledgeable supervision. Medical practitioners and health care providers can provide significant assistance to help athletes benefit from D3, whether it comes from the sun, appropriate sunlamps, and/or capsules.

REFERENCES
1. John J. Cannell, MD, received his medical degree from University of North Carolina and has specialized in emergency medicine, general practice, and psychiatry. He founded the non-profit Vitamin D Council in 2003.
18. Dr. Roth became interested in studying vitamin D supplementation for athletes after having experienced positive changes with running when taking large doses of vitamin D3. He writes, “I’ve been taking 20,000 IU/day for more than three years and have seen enormous benefit to my running. I had been overuse-injury prone for about 30 years and found whenever I exceeded 12 miles on a run, I would experience an injury. I was always more injury-free in the summer than in the winter. With high-dose vitamin D3, I run 1,726 miles with one run of 21 miles, eight 18-mile runs, seven 16-mile runs, and ten 15-mile runs. They were all without overuse injury. I had close to the same mileage in 2013 (1,543 miles) without overuse injury. I had close to the same mileage in 2013 (1,543 miles) without injury. These were in my 70th and 71st years of age. I’ve reviewed my D3 intake and results with Dr. Cannell and he is supportive of my high D3 levels.”

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