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Abstract

**Background:** Vitamin D is an essential vitamin and hormone required for healthy musculoskeletal status as well as preventing many other conditions. Adequate vitamin D status is essential to the practicing chiropractor as a therapeutic agent to ensure the patients overall musculoskeletal health and appropriate response to other treatments such as the chiropractic adjustment.

**Objective:** To review current literature and provide recommendations to the Doctor of Chiropractic regarding vitamin D.

**Method:** The discussions herein will evolve through 4 major sections: 1) History and Physiology, 2) Epidemiology of Hypovitaminosis D and Definitions, 3) Vitamin D Effects on the Musculoskeletal system, and 4) Vitamin D Therapeutics.

**Conclusion:** Efforts should be made to ascertain vitamin D status in the patient. Identifying risk factors for vitamin D deficiency should be in the forefront when taking a patient’s initial history. The gold standard in determining vitamin D status is the 25(OH)D assay. If inadequate, a treatment plan should be devised to restore the vitamin D levels. This process usually takes several months and involves a multipronged effort.

**Key Indexing Terms:** Vitamin D, Chiropractic, neuromusculoskeletal health.
Objective

This work represents an exploratory review of the literature on the subject of Vitamin D. The purpose of this article is to familiarize the reader with the current accepted model of basic vitamin D metabolism and regulation and the recent advances of research in enhancing our understanding on the variety of functions and therapeutic effects of this vital vitamin as it pertains to neuromusculoskeletal health care, particularly in the field of chiropractic.

This article will review the recent advances in our understanding of the impact of vitamin D on the neuromuscular system, its health and function and its import to the Doctor of Chiropractic. The article will conclude by presenting clinical guidelines for the chiropractor suggesting to the doctor proper identifications of risk factors, screening procedures, assessments, diagnosis, treatment protocols and follow up.

It is the author’s opinion that poor vitamin D status is a common co-morbidity of the typical chiropractic patients. This belief is supported by the high epidemiologic incidence of poor vitamin D status coupled with the correlated frequency of neuromusculoskeletal complaints from these patients. Left undetected, it is the author’s opinion that a poor vitamin D status lends to diminished neuromusculoskeletal health and function and complicates and compromises the treatment of the chiropractic physician.

The following review of the current literature is designed to bring the issues described above to the forefront of the chiropractic profession and to the individual chiropractic physicians as they manage the neuromusculoskeletal health of their patients. It is the author’s hope that this
article will serve as a flagship calling attention to issues discussed herein and will spark further research and investigation.

**Introduction**

It was in the early 1900's when scientists first became aware of the substance vitamin D. Their early studies focused on its association with sunlight at its cure for rickets. Not many years after its discovery and branding as the sunshine vitamin and the bone health vitamin little scientific investigation was put forth to further understand this peculiar vitamin/hormone.

In the past 15 years, vitamin D has once again caught the attention of the scientific community and much has developed in increasing our understanding of this vitamin. We have recently discovered the vitamin D receptor (VDR) on the muscle; associated with this finding we are just beginning to understand how important vitamin D is to the overall health and function of the muscular system.

**Discussion**

The following discussion will evolve through 4 major sections: 1) History and Physiology, 2) Epidemiology of Hypovitaminosis D and Definitions, 3) Vitamin D Effects on the musculoskeletal system, and 4) Vitamin D Therapeutics.

**Part I – History and Physiology**

**Physiology**

In the context of Chiropractic and Vitamin D, the most immediate issue that comes to mind is bone mineralization health in the elderly; although this is a fundamental function of vitamin D
in the vertebrate organism, there is much more organic utilization of this essential vitamin. The major and most understood function of vitamin D is its regulation of serum calcium levels. When serum calcium levels are low, vitamin D acts to raise calcium in the blood by increasing absorption from the intestines and resorption form bone by increasing osteoclast activity; the opposite is also true when serum calcium levels are high.

Vitamin D is represented by a body of seco-steroids that demonstrate antirachitic activity. The three most functional forms are vitamin D₃ (cholecalciferol), 25-hydroxyvitamin D₃ (calcidiol), and 1,25-dihydroxyvitamin D₃ (calcitriol); Calcidiol is the serum marker utilized for assessing vitamin D status of a patient, whereas the later most member mentioned (calcitriol) is the most metabolically active form found in the human organism.¹

Vitamin D (cholecalciferol) is converted from a previtamin when catalyzed by radiant energy from the sun in the skin. Since the body is capable of self production of vitamin D₃, Vitamin D does not fit the classic definition of a vitamin.² In fact, since vitamin D’s initial discovery and classification as a lipid soluble vitamin, it has been recognized that in vivo the metabolism and function of vitamin D fits more of the classification of a steroid hormone, although by convention, it is still considered a vitamin.

Figure 1
Plasma vitamin D is obtained from one of two sources, either the synthesis of Vitamin D₃ in the skin or from the diet. In circulation both dietary and skin derived vitamin D is found associated with a vitamin D-binding Protein (DBP) to make this fat soluble vitamin hydrophilic. (³) After losing only a minimal amount of circulating vitamin D to the adipose stores, the remainder is processed by hepatocytes to 25-hydroxyvitamin D [25(OH)D]. Post hepatic processed 25(OH)D reenters general circulation found once again bound to DBP where it is eventually recognized by megalin of the renal tubular cells. Megalin induces renal endocytic transport of the 25(OH)D-DBP which then disassociates allowing 25(OH)D to enter the renal mitochondria where it is converted into the active form of vitamin D, 1,25-dihydroxyvitamin D [1,25(OH)₂D].

A Major control point of the conversion of vitamin D into its active form is mediated by the renal mitochondrial enzyme, P450-25-hydroxyvitamin D-1-hydroxylase (1-OHase). 1-OHase is up regulated by hypocalcaemia, hypophosphatemia, parathyroid hormone (PTH), as well as estrogen and prolactin during pregnancy and lactation. (³)

Circulating active 1, 25(OH)₂D binds to its vitamin D receptor (VDR) found in the intracellular environment of many tissues in the body which induces a series of interactions that culminates in the binding of several transcriptional factors that facilitate the increased or decreased expression of vitamin D-responsive genes.

In a hypocalcaemic state, 1,25(OH)₂D binds to the VDR in the cells of the small intestine, providing a negative feedback loop by promoting the expression of the epithelial calcium channels, calcium-binding protein, calcium-dependant ATPase, as well as several other brush
boarder proteins which together synergistically increase the efficiency of calcium absorption roughly 30%. (3)

Dr. Holick PhD, MD, who is known for his lifelong work with vitamin D points out, “Although vitamin D is associated with bone health, the principal physiological function of vitamin D is to support the serum calcium within a physiologically acceptable range in order to maintain neuromuscular and cardiac function and a multitude of other metabolic activities. Thus, when dietary calcium is inadequate to satisfy the body’s requirement for calcium, this results in vitamin D becoming a catabolic hormone that mobilizes calcium stores in the skeleton.” (3)

1,25(OH)₂D induces calcium resorption from bone by interacting with the VDR in the osteoblasts, the master regulator of bone metabolism. Through a series of interactions, the osteoblasts stimulated by 1,25(OH)₂D signal the maturation of preosteoclasts to become fully functional bone resorbing osteoclasts. With a new army of mature osteoclasts, a flood of calcium is freed from the bone reserves and released into general circulation.

**Vitamin D and Bone Mineralization- The Vitamin D Paradox**

Despite the interaction between 1,25(OH)₂D with the VDR in the osteoblast, there is no evidence that vitamin D enhances or even is needed for bone mineralization. This is demonstrated by the effective treatment of rickets with exclusive high calcium and phosphorus diets in vitamin D deficient subjects. (4; 5)

These findings may seem counterintuitive due to the fact that vitamin D is known as the ‘bone health vitamin’ and the miracle cure for rickets. The overarching action of vitamin D is to increase serum calcium levels, as discussed in detail earlier, it does this by increasing absorption in the GI tract and resorption from bone. Despite the fact that vitamin D actually signals
resorption of calcium from bone, the overall net effect of vitamin D is that more calcium is absorbed by the intestine rather than resorbed from bone, netting an overall increased bioavailability of calcium and increased bone density. Contrast that with an individual who is vitamin D deficient who nets more resorption from bone than absorption from dietary sources, netting decreased bone density.\(^6\)

**Rickets**

Rickets, a bone softening disease due to a vitamin D deficiency, proved to be a vexing condition that took a long time to solve. Although evidence of rickets has been found in the Neanderthal man, scientific descriptions were written in the 1600’s and heavy investigation was conducted in the 1800’s, it was not until 1922 when McCollum et al. correctly identified the elemental dietary deficiency and coined the name “vitamin D.”\(^2; 7\)

Shortly thereafter, it was well established that both vitamin D and UV light were effective therapeutic agents in preventing and treating rickets. However, it was never appreciated how intimately associated these two factors where until 1925 when Hess and Weinstock demonstrated that the antirachitic vitamin D was made in the skin upon UV irradiation.\(^2; 8; 9\)

Once the puzzle of rickets had been solved research turned its investigative eye away from vitamin D. Recently interest has come full circle and investigators have once again been looking at this important vitamin. Many more therapeutic benefits have been identified and associated with adequate vitamin D serum levels.
Part II: Epidemiology of Hypovitaminosis D and Definitions

Before we delve into the clinical implications of a poor vitamin D status in the setting of manual medicine, a clinician must first become acquainted with the prevalence of a poor status in their population and the respective definitions of poor verses adequate status and the variable that predispose an individual to having a poor status.

Appropriate status definitions

In an assessment of the literature searching for the definitions of optimal and poor vitamin D status, there are none universally accepted. Presented here are those definitions that have the strongest voice in the literature by the leading experts.

It is generally accepted that a serum 25-hydroxyvitamin D level below 20 ng/mL is the definition of a vitamin D deficiency. Conversely, a serum level greater than 30 ng/mL is the definition of a sufficient level, thus making any serum levels of 21 – 29 ng/mL the definition of an insufficiency. Intoxication is noted when levels are above 150 ng/mL. (10) (11) (12) (13) (14) (15)

A much more controversial argument is that of the definition of an optimal status, more than that of merely a sufficient status. Sufficiency simply demarcates the serum level of 25-hydroxyvitamin D were there are no longer blatant pathological effect due to the lack of vitamin D, whereas an optimal status is arguably the point where there is maximal physiologic performance and health.

<table>
<thead>
<tr>
<th>Status</th>
<th>Serum 25-hydroxyvitamin D ng/mL</th>
<th>Serum 25-hydroxyvitamin D nmol/L</th>
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</thead>
<tbody>
<tr>
<td>Deficient</td>
<td>&lt; 20</td>
<td>50</td>
</tr>
<tr>
<td>Insufficiency</td>
<td>21-29</td>
<td>52 - 72</td>
</tr>
<tr>
<td>Sufficient</td>
<td>&gt; 30</td>
<td>75</td>
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<tr>
<td>Desired*</td>
<td>50</td>
<td>125</td>
</tr>
<tr>
<td>Intoxication</td>
<td>&gt;150</td>
<td>374</td>
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</tbody>
</table>
The definition of sufficiency is based upon the inverse relationship between levels of 25-hydroxyvitamin D and parathyroid hormone in the serum, since low vitamin D levels are associated with secondary hyperparathyroidism and resultant poor calcium absorption and progressive bone turnover and loss. \(^{(11)}\) \(^{(16)}\) \(^{(17)}\) \(^{(18)}\) \(^{(19)}\) \(^{(20)}\) \(^{(21)}\) Therefore, according to the research, a sufficient vitamin D status is the point at which parathyroid hormone levels are minimized \(^{(11)}\) \(^{(22)}\) \(^{(18)}\) and calcium absorption is maximized. \(^{(11)}\) \(^{(23)}\) This is observed beginning at a serum level of 30 ng/mL of 25-hydroxyvitamin D. This measurement and definition is ultimately premised around the pathophysiology of bone, dealing with intestinal calcium absorption and bone resorption which is the central focus of the initial research on vitamin D associated with rickets; however it neglects the immerging body of research revealing the multiplicity of other physiologic functions that vitamin D is involved in and which will be discussed later in this paper. This oversight allegedly may put our current sufficient vitamin D status in question.

Many experts have argued a true optimal vitamin D status is more close to 50 ng/mL for maximal systemic physiologic function for the patient, more than that of solely the skeletal system. \(^{(24)}\)

**Prevalence of hypovitaminosis D:**

The need for a physician of neuromusculoskeletal health and function to be Omniscient of the prevalence of hypovitaminosis D is imperative. As discussed latter in this paper, low vitamin D status has profound effects on the neuromusculoskeletal system and could be the primary problem of a patient’s chief complaint or a complicating factor. If the physician is not prudent in their clinical assessment and diagnosis, a low vitamin D status could be overlooked and complicate the patient’s prognosis and delay reparative healing.
In an assessment of the prevalence of hypovitaminosis D context matters. The literature abounds with varying estimates and figures all conditioned on varying parameters and sub-classifications of patient bases. A researcher must note the context and parameters of the estimate.

Michael Holick, PhD, MD, a leading expert of vitamin D campaigns that hypovitaminosis D is a worldwide epidemic and calls to attention the abundant reports that inadequate levels are found frequently in numerous cohorts including, “healthy children\textsuperscript{11} [25] (26) (27) (28) (29), young adults,\textsuperscript{11} [21] (30) (31) especially in African Americans,\textsuperscript{11} [25] (32) (33) (31) (34) and middle-aged and elderly adults.\textsuperscript{11} (35) (36) (19) (20) (37) (38) (39) (40) (41) (42) (29) (31) (43) (44) (45) (46) (47) (48) Based upon the definitions of inadequate and deficient serum levels of 25-hydroxyvitamin D, it is estimated that more than 1 billion people worldwide have an insufficient vitamin D status.\textsuperscript{10}

No population is spared from being at risk for hypovitaminosis D. Surprising to many this is not a third world disease as is commonly found with a full blown case of rickets. “No one is immune from vitamin D deficiency. This includes both children and adults living in the United states, Europe, Middle East, India, Australia and Asia. These studies suggest that upwards of 30 – 50% of children and adults are at risk of vitamin D deficiency.\textsuperscript{49} (50) (51) (31) (52) (28) (36) (53) (54) (55) Dr. Holick summarizes the following:

Vitamin D inadequacy has been reported in approximately 36% of otherwise healthy young adults and up to 57% of general medicine inpatients in the United States and in even higher percentages in Europe. Recent epidemiological data document the high prevalence of vitamin D inadequacy among elderly patients...
and especially among patients with osteoporosis. Factors such as low sunlight exposure, age-related decreases in cutaneous synthesis, and diets low in vitamin D contribute to the high prevalence of vitamin D inadequacy.\(^{(11)}\)

The following section will continue to discuss the variety of variables that influence the vitamin D status of a given patient and explain the epidemiologic differences seen in different cohorts.

**Vitamin D Status Variables**

Vitamin D is introduced into circulation either one of two ways: 1) through the diet or 2) it is cutaneously synthesized.

**Dietary sources**

Very few foods contain natural sources of Vitamin D. Of those available, fish, eggs and fortified dairy products are the most common sources of vitamin D in the diet.

**Cutaneous Synthesis Variables**

The stimulant for cutaneous synthesis of vitamin D is solar radiation; specifically in the spectrum of ultraviolet B (UVB). Anything that reduces UVB radiation to the earth’s service, absorption into the skin, or the skin’s ability to synthesis vitamin D will diminish the cutaneous production of vitamin D\(_3\).\(^{(49)}\)

**Atmospheric Filtration.** The number one filter of UVB radiation to the earth’s surface is the angle in which the radiation penetrates the ozone, known as the zenith angle. The zenith angle is increased in three ways: 1) In the early morning and late afternoon; 2) during the winter time as the angle of the axis of the earth tilts away from the sun; and 3) it is increased the further you live from the equator... In all three of these cases, the literature documents that there is
decreased cutaneous synthesis of vitamin D$_3$. In case three, there is a gradual gradient of decreased UVB penetration through the ozone the further you get away from the equator; although there is no definite latitude dividing productive vitamin D$_3$ synthesis or the lack thereof, some experts have demarcated the latitude of 35 degrees or further north as the point when one should consider a lack of UVB to their patient’s skin.\textsuperscript{(24)} To put this point of reference in context of the United States, note that in figure 2, Los Angeles, Phoenix, Little Rock, Atlanta, and Raleigh are the major cites that approximate the 35$^{th}$ latitude. Studies in Boston have shown that despite subjects only wearing only a swimming suit in the middle of the winter at midday with clear skies, there was no appreciable cutaneous synthesis of vitamin D.\textsuperscript{(25)}

**Cutaneous Filtration.** There are three major filters that diminish the skin’s absorption of UVB radiation: 1) clothing; 2) sunscreen; and 3) skin pigmentation. It is not uncommon to find both children and adults deficient of vitamin D even in the sunniest places of the earth due to the practice of covering nearing all the skin to protect it from the sun.\textsuperscript{(49)(50)(51)} Sunscreen with as little of an SPF as 15 has been documented to absorb 99% of all UVB radiation and proportionately decrease cutaneous synthesis of vitamin D$_3$.\textsuperscript{(49)(56)} Melanin behaves similarly to sunscreen and absorbs more UVB radiation the more it is present in the skin.

**Subcutaneous Inhibitions.** Factors influencing the cutaneous synthesis of vitamin D$_3$ include 1) aging, which reduces the availability of 7-dehydrocholesterol by approximately 25% by the age
of 70 and thus reduces the synthesis capacity by 75%; (49) (57) 2) obesity, which is presumed to reduce availability of vitamin D because it is trapped in the fat stores; and 3) medications such as anti-seizures and glucocorticoids have deleterious effects on vitamin D synthesis. Patients with fat malabsorption are also at risk of vitamin D deficiency.

Taking into account all these variables influencing circulating vitamin D a hypothetical patient with a greatly increased risk of being vitamin D deficient would be an older, obese African American individual living in a northern latitude above 35 degrees lacking any sensible sun exposure and dietary sources of vitamin D. It however, is not clinically sound to assume a patient lacking one or more of these variables could not still be at risk of hypovitaminosis D.

Special Considerations for High Risk Populations

Vitamin D Status in Mothers and Infants

In 2007, Dr. Lee et al., (58) assessed the vitamin D status of mothers and newborn infants. The majority of their sample population was African Americans in the middle of a Boston winter, identifying them as a high risk population due to their dark skin and northern latitude. In the study they found that there was a positive association between mother’s vitamin D status and their infant. They also found that 50% of the mothers assessed were vitamin D deficient and 65% of the newborn infants. The low status of the developing infant is most alarming due to the potential of bone deformities and other conditions.

In 2008, Dr. Anne Marewood et al., studied the association between cesarean deliveries and vitamin D status of the mother. (59) Dr. Marewood points out the clear association at the turn of the 20th century between c-section deliveries due to a rachitically deformed pelvis. Although
rickets has been mostly eliminated, slight pelvic deformities exist as well as the prodrome of muscular issues due to low serum vitamin D levels. The results of their study found that mothers who were vitamin D deficient had a 400% increased chance of having a c-section delivery.

Part III: Vitamin D Effects on the Neuromusculoskeletal system

The effects of hypovitaminosis D on the skeletal system have been long established and are well known. The link between low vitamin D and rickets in the immature skeleton and osteopenia/osteoporosis in the mature skeleton are irrefutable and are still seen today even in developed countries. \(^{(49)}\)

The Primary level that the doctor of chiropractic approaches the typical patient with is the health and dynamic of the neuromusculoskeletal system. It is in this area that a wealth of new research is being performed. The following sections will explore the recent literature expanding our traditional understanding of vitamin D and the health of the neuromusculoskeletal system.

The VDR

Evidence is culminating that vitamin D have extraskeletal function. It seems that vitamin D is more than just the bone vitamin. More and more cells from divers tissues and organs have been discovered to possess the vitamin D receptor (VDR), the intracellular protein vitamin D activates. Skeletal muscle is among the cells to posses the VDR. \(^{(10)}\) \(^{(59)}\) \(^{(12)}\) \(^{(49)}\) \(^{(60)}\) Brain, Prostate, breast, and colon tissues and immunologic cells also have the VDR, \(^{(10)}\) \(^{(59)}\) \(^{(61)}\) \(^{(62)}\) \(^{(63)}\) \(^{(64)}\) some of
these also have enzyme 25-hydroxyvitamin D-1alpha-hydroxylase.\(^{(10)}\)\(^{(59)}\)\(^{(61)}\)\(^{(62)}\)\(^{(64)}\) Directly or indirectly, vitamin D3, controls more than 200 genes.\(^{(59)}\)\(^{(61)}\)\(^{(65)}\)

**Vitamin D and Falls**

It has long been understood that a vitamin D deficiency is a risk factor for increased incidence of fractures. The tale the research is more recently revealing is even more intriguing; not only is there an increased incidence of fracture to bone, but there is an increased incidence of falls in the elderly, the event that prefaces the fracture. A meta-analysis assessing 5 clinical trials with a cumulative 1,237 participants demonstrated that higher serum vitamin D levels reduced the risk of falls 22%.\(^{(12)}\)

As the this new knowledge is brought to light, enumerating questions come to a researches mind that challenge the basic understanding that vitamin D is merely the bone health vitamin. If a poor vitamin D status predisposes one to a fall, obviously this is more than the issue of the density of the bones, the function of vitamin D must be involved somewhere in the muscular or neurologic pathways dealing with balance, coordination, and strength.

**Vitamin D and Musculoskeletal Function**

As the research linking hypovitaminosis D and increased incidence to falls has come to light, there has been a birth of studies correlating musculoskeletal function and vitamin D levels. This new facet in the investigation of vitamin D proves to be an immature and promising area of research. The mere presence of the VDR on the skeletal muscles attests to vitamin D’s requirement for optimal muscular function.
It has been validated by several researchers that vitamin D deficiency causes muscular weakness\textsuperscript{(59)}\textsuperscript{(66)}\textsuperscript{(12)}\textsuperscript{(67)} and further has linked with proximal mm weakness, increased body sway which precipitates the increased risk of falls.\textsuperscript{(49)}\textsuperscript{(68)}\textsuperscript{(69)}\textsuperscript{(70)} One of the first studies that tuned into this area was executed by Heike Bischoff-Ferrari \textit{et al.} in 2004.\textsuperscript{(68)} This study took two elderly populations, one vitamin D sufficient and the other deficient and put them through a series of daily tasks requiring their lower extremities (ie walking, sit to stand time, etc.) and measured their time, efficiency, and coordination. The researches concluded “In both active and inactive ambulatory persons aged >60y, 25(OH)D concentrations between 40 and 94 nmol/L are associated with better musculoskeletal function in the lower extremities than are concentrations <40 nmol/L.”

In another study, Heike Bischoff-Ferrari \textit{et al.} analyzed performance speed and proximal muscle strength in contrast to serum levels of 25-hydroxyvitamin D.\textsuperscript{(12)} The results revealed that both speed and strength improved proportionately as serum levels were raised from 4 to 16 ng/mL and continued to improve as levels reached 40ng/mL.

Trialing on with these reports, Kentz Willis \textit{et al.} brings application in the arena of sports, pointing out the prevalence of vitamin D deficiency in our athletic populations and citing several studies that hint at the potential of a sufficient vitamin D status being able to improve our athletes’ function if they are currently deficient.\textsuperscript{(71)}

Even Dr. Marewood’s study discussed previously linking maternal hypovitaminosis D and increased incidence of c-section deliveries hints of the effects of vitamin D outside of calcium deposition/resorption in bone and probably in the area of muscular strength and function.\textsuperscript{(72)}
The complaints can range from anything from headaches in their variety of forms to local or global aches and pains, to balance or proprioceptive limitations.

**Breadth of Developing Research**

Outside of the neuromusculoskeletal topics discussed herein, there is a whole other body of other conditions which have been associated with inadequate vitamin D levels including: type 1 diabetes mellitus, multiple sclerosis, rheumatoid arthritis, infections, high blood pressure, congestive heart failure, schizoprehenia, depression, dementia, pre-eclampsia, and tuberculosis; as well as overall cardiovascular mortality, cancer incidence and mortality, and autoimmune diseases such as multiple sclerosis. Cancers associated with low vitamin D levels are colorectal, breast, and prostate; Supplementation has proven to reduced the risk.

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**Part IV: Vitamin D Therapeutics**

This section is a compilation of guidelines derived from the vast body of literature for the appropriate screening, assessment, diagnosis, and treatment/prevention strategies.

**Screening**

Risk factors predisposing to low circulating 25-hydroxyvitamin D levels are: lack of dietary intake, minimal sun exposure or the use sunscreen or clothing to cover up when in the sun, living north of the 35th latitude, dark skin pigmentation, the presence of osteopenia, and older age. All of these factors should be weighed into consideration when managing a patient’s health care. Other factors to take into consideration are the overall health of the patient, the
nature and tissue source of the chief complaint, the effects of any drugs they may be taking and any fat malabsorption syndromes.\textsuperscript{(66)}

A potential yellow flag raising the suspicion of possible hypovitaminosis D while a patient under care for a musculoskeletal complaint in a chiropractic office or another doctor of manual medicine is a failure of a trial of care, resulting in lack of progress or slower than anticipated recovery/healing.

**Assessment and Diagnosis**

Based upon the evaluation of risk factors represented in a given patient a recommendation of vitamin D rehabilitative strategies could be recommended, however without an appropriate measurement of the vitamin D status of the patient it is a clinical shot in the dark. It is therefore recommended to the chiropractic physician and other like doctors to obtain vitamin D lab work for their patient when possible.

A point of confusion for many clinicians is which test to order when evaluating their patient’s vitamin D status. The active form of vitamin D is $1,25(\text{OH})_2\text{D}$ also known as vitamin $D_3$. The primary vitamin D metabolite in the serum is $25(\text{OH})\text{D}$ or vitamin $D_2$. “Although $1,25(\text{OH})_2\text{D}$ is the active form of vitamin D, it should not be measured to determine vitamin D status. It usually is normal or even elevated in patients with vitamin D deficiency.”\textsuperscript{(66)}\textsuperscript{(16)}\textsuperscript{(78)}\textsuperscript{(79)} The standardized measure of vitamin D status is thus $25(\text{OH})\text{D}$ as this represents the serum vitamin D contributions from dietary intake and cutaneous synthesis.\textsuperscript{(66)}\textsuperscript{(16)}\textsuperscript{(36)}

Laboratories call upon diverse methodologies to assess $25(\text{OH})\text{D}$ serum levels. The two most common assays are the DiaSorin radioimmunoassay and the liquid chromatography mass
spectroscopy assays (LCMSMS). These two assays are, however, not created equal. The radioimmunoassay measures the total 25(OH)D, whereas, the LCMSMS measures both 25-vitamin D_2 and 25-vitamin D_3, distinguishing between the two. The added distinction provided by the LCMSMS is useful when assessing the effectiveness of the therapy provided to a vitamin D deficient patient. For example, Vitamin D_2, is only available as a pharmaceutical; if a patient were being supplemented with this and the follow-up assay did not show an increase in serum vitamin D_2 it would be immediately recognized that the patient was ineffectively absorbing the dietary supplement and thus failing to respond to the therapy. Both the radioimmunoassay and the LCMSMS meet the gold standard requirements of measuring 25(OH)D, however, the added detail with the LCMSMS makes this assay preferential when available.

As discussed earlier in this paper evaluation and diagnosis should be based upon the definitions given in the Table 1.

<table>
<thead>
<tr>
<th>Treatment Strategies and Considerations</th>
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**Therapeutic Intervention Options**

**Supplementation.** The two main sources of dietary vitamin D is either vitamin D_2 or D_3. Vitamin D_3 is nearly three times more effective in sustaining 25(OH)D levels in the blood. In practical application, this means you would have to supplement three times the amount of vitamin D_2 to have the same effect as D_3.

Vitamin D_3 is derived from all vertebrate animals and is synthesized by the exposure to ultraviolet B radiation to the skin. Vitamin D_2 is derived from invertebrates, phytoplankton, and
fungi. Vitamin D\textsubscript{2} can also be produced by exposing foods to ultraviolet radiation. Neither vitamin D\textsubscript{2} nor D\textsubscript{3} are the biologically active form in the blood.

Vitamin D\textsubscript{3} is more stable than D\textsubscript{2} when in powder form. Vitamin D\textsubscript{2} is more chemically sensitive to light, temperature, and humidity when compared to D\textsubscript{3}. Thus, Vitamin D\textsubscript{2} is more likely to contain impurities, which may or may not be biologically active.

**Ultraviolet B Radiation.** UVB radiation can be obtained either from natural sunlight or artificial lighting; Both sources have proven effective in evoking cutaneous synthesis of vitamin D and both a feasible treatment options. “Exposure to one minimal erythemal dose while wearing only a bathing suit is equivalent to the ingestion of approximately 20,000 IU of vitamin D\textsubscript{2}.”\textsuperscript{(10)}\textsuperscript{(59)} \textsuperscript{(61)(66)(79)} Artificial sources of UVB, when tested, typically emit 2 to 6% UVB.\textsuperscript{(10)}\textsuperscript{(80)}\textsuperscript{(81)}\textsuperscript{(82)}\textsuperscript{(83)}

**Prevention**

Based upon the pretext of merely preventing deficiency, the US Food and Drug Administration recommends a daily intake of 400 IU/day or vitamin D\textsubscript{3}.\textsuperscript{(11)}\textsuperscript{(84)} The European commissioned Scientific Committee for Food makes a similar recommendation for those >65 year-old or who may not be getting adequate sun exposure.\textsuperscript{(11)}\textsuperscript{(85)}

In order to sustain a serum vitamin D status that exceeds 30 ng/mL, or simple a sufficient level, it has been shown and daily intake of 1000 IU/day of vitamin D\textsubscript{3} is required.\textsuperscript{(11)}\textsuperscript{(86)}\textsuperscript{(23)}\textsuperscript{(87)}\textsuperscript{(88)}

Seasonality and sun exposure must be taken into consideration when devising appropriate supplemental levels of vitamin D.

It has been estimated that if the general population were to receive a Dietary supplementation of vitamin D, deficiency would be prevented in 98%.\textsuperscript{(11)}\textsuperscript{(89)}\textsuperscript{(90)} It has also been demonstrated
that vitamin D levels have been appropriately maintained in the elderly with the combination of supplementation and natural and artificial sun exposure.\textsuperscript{11} \textsuperscript{13} \textsuperscript{91} \textsuperscript{92} \textsuperscript{93} \textsuperscript{94} \textsuperscript{95} \textsuperscript{96} \textsuperscript{97} \textsuperscript{98} \textsuperscript{99} \textsuperscript{80} An interesting study reveals simply putting UV lights in a nursing home effectively raised the serum vitamin D levels in the elderly occupants.

Sensible sun exposure, defined as direct sun exposure to the arms and legs for 5 to 10 minutes between 10 am and 3 pm in the seasons of late spring, summer and early fall, has been proven to prevent vitamin D insufficiency.\textsuperscript{11} \textsuperscript{89} \textsuperscript{102}

**Toxicity**

Toxic levels of serum vitamin D are seen above 150 ng/mL where symptoms associated with hypercalcemia and hyperphosphatemia begin to arise.\textsuperscript{10} \textsuperscript{59} \textsuperscript{62} \textsuperscript{87} \textsuperscript{103} \textsuperscript{104} The literature is largely devoid of reports of vitamin D toxicity despite the fact that vitamin D is a fat-soluble vitamin and more difficult to excrete than water soluble vitamins. No accounts of vitamin D toxicity have been associated with long term sun exposure are found in the literature.\textsuperscript{11} \textsuperscript{16} \textsuperscript{79}

In regards to supplementation, vitamin D toxicity has been reported when dietary intake exceeded 50,000 IU/day.\textsuperscript{10} \textsuperscript{59} \textsuperscript{61} \textsuperscript{62} \textsuperscript{87} \textsuperscript{103} \textsuperscript{104} A documented regimen of 10,000 IU/day of vitamin D\textsubscript{3} for 5 months failed to produce any signs of intoxication. Therapeutic treatment plans of 4,000 IU/day for 3 months and 50,000 IU/week for 2 months have also proven to be safe.

**Treatment of Vitamin D Deficiency**

Patients with severely deficient levels of circulating vitamin D should be aggressively treated, particularly if they are children to prevent rickets.\textsuperscript{10} \textsuperscript{67} \textsuperscript{105} \textsuperscript{106} \textsuperscript{107} Dr. Hollick, with over 3
decades of time spent in research and treatment of vitamin D deficiencies recommends, “The best method of treating vitamin D deficiency is an oral dose of 50,000 IU/week of vitamin D₂ for 8 weeks then checking 25(OH)D levels. In some cases, another once-weekly 8-week course of 50,000 IU of vitamin D₂, may be necessary to boost 25(OH)D levels into the desired range of more than 30 to 50 ng/mL.” (11) (16) (13)

Once the patient’s vitamin D levels have been successfully rehabilitated the treatment needs to shift to support the maintenance of the re-established levels. This maintenance should include a protocol of 1,000 IU/day of dietary vitamin D and additional support from regular UVB radiation exposure.

**Conclusion**

Vitamin D is an essential vitamin and hormone required for healthy musculoskeletal status as well as preventing many other conditions. Adequate vitamin D status is essential to the practicing chiropractor as a therapeutic agent to ensure the patients overall musculoskeletal health and appropriate response to other treatments such as the chiropractic adjustment.

Efforts should be made by the chiropractic physician to ascertain vitamin D status in their patients. Identifying risk factors for vitamin D deficiency should be in the forefront when taking a patient’s initial history. The gold standard in determining vitamin D status is to order a 25(OH)D laboratory assay when in the scope of practice of the doctor. (108) If inadequate levels are identified a treatment plan should be devised to restore the vitamin D levels. This process usually takes several months and involves a multipronged effort.
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