Vitamin D is a fat soluble vitamin with a well-known general metabolism and actions in bone structure and immune system regulation (Grant et al., 2020a). Vitamin D3 or oral vitamin D is converted to 25(OH)D in the liver and 1,25(OH)2D (calcitriol) in the kidneys. Vitamin D helps maintain tight junctions while viruses destroy the junction integrity and reduce the replication of rotavirus both in vitro and in vivo (Grant and Garland, 2003).

Vitamin D enhances cellular innate immunity partly through the induction of antimicrobial
peptides, including human cathelicidin, LL-37 and 1,25(OH)2D (Liu et al., 2006), defenses and modulate cytokine storm of pro-inflammatory Th1 cytokines, such as tumor necrosis factor α and interferon γ (Huang et al., 2020, Sharifi et al., 2019).

Vitamin D exhibits direct antimicrobial activities against a spectrum of microbes, including Gram-positive and Gram-negative bacteria, enveloped and non-enveloped viruses, as well as fungi (Grant and Garland, 2002, Grant et al., 2020a).

Serum 25(OH)D concentrations tend to decrease with age (Grant et al., 2020a), which may play an important role in COVID-19 case-fatality rates (CFRs).

Vitamin D supplementation also enhances the expression of genes related to antioxidantization (glutathione reductase and glutamate–cysteine ligase modifier subunit) with antimicrobial activities (Colunga Biancatelli et al., 2020) that has been proposed to prevent and treat COVID-19 (Grant et al., 2020a). Seasonal influenza infections can cause mortality due to respiratory involvement generally peak in winter (Grant et al., 2020a), which are partly caused by seasonal solar UVB doses that affect vitamin D concentrations. In addition, some weather conditions of low temperature and relative humidity can allow the influenza virus to survive longer outside the body than in warmer conditions.

Clinical findings and epidemiologic studies on vitamin D and COVID-19

The first step in developing a hypothesis is to consider the epidemiological and clinical findings regarding the disease of interest and to investigate the relationship of these results with 25(OH)D concentrations. An observational study showed that concentrations of 38 ng/ml or higher were associated with a significant ($P < 0.0001$) more than two-fold reduction in the risk of developing acute respiratory syndrome (17% vs. 45%) (Huang et al., 2020).

The recent epidemiological and clinical studies indicate that COVID-19 infection is associated with the increased secretion of pro-inflammatory cytokines, C-reactive protein (Huang et al., 2020), increased risk of pneumonia (Wang et al., 2020), sepsis, acute respiratory distress syndrome, and heart failure (Zhou et al., 2020). Case fatality rates in China ranged from 6% to 10% for those with cardiovascular diseases, chronic respiratory tract diseases, diabetes, and hypertension (Wang et al., 2020).

We know that Corona viruses destroy the lung epithelial cells and facilitate pneumonia by increasing the secretion of Th1-type cytokines such as interferon γ, as part of the innate immune response and the cytokine storm. However, COVID-19 infection also initiates increased secretion of the Th2 cytokines (e.g., interleukins 4 and 10) that suppress inflammation (Sabetta et al., 2010).

Clinical trials in vitamin D on prevention and treatment COVID-19

Some clinical trials on vitamin D showed decreased incidence and severity of COVID-19. A high-dose (250,000 or 500,000 iu) of vitamin D3 trial was used in COVID-19 patients under ventilation in intensive care unit in Georgia with the mean baseline 25(OH)D concentration of 20–22 ng/ml. The findings showed that hospital stay reduced from 36 ± 19 days in the control group to 25 ± 14 days in the 250,000-iu group (25(OH)D, 45 ± 20 ng/ml) and 18 ± 11 days in the 500,000-iu group (25(OH)D, 55 ± 14 ng/ml), $P = 0.03$ (Han et al., 2016). Moreover, the data support the role of higher 25(OH)D concentrations in reducing the infection incidence and death from acute respiratory tract syndrome, including those from influenza (Cianferotti et al., 2017). Thus, vitamin D3 supplementation should be started or increased several months before winter to raise 25(OH)D concentrations to the range necessary to prevent acute respiratory tract syndrome.

Studies reviewed various optimum vitamin D3 concentrations such as 25(OH)D concentrations of 20–30 ng/ml or 38 ng/ml as the appropriate concentrations. The optimal range appears to be in
the range of 40–60 ng/ml or 100–150 nmol/l) (Sabetta et al., 2010).

What is the optimum vitamin D dosage for loading dose and maintenance?

To achieve the optimum vitamin D3 levels, approximately half the population should take at least 2000–5000 iu/d of vitamin D3 (Heaney et al., 2003). Various loading doses were proposed for achieving a 25(OH)D concentration of 30 ng/ml. One study showed that a weekly or fort nightly dose totaling 100,000–200,000 iu over 8 weeks (1800 or 3600 iu/d) (van Groningen et al., 2010) as loading. However, to achieve the concentration of 40–60 ng/ml higher loading doses should be prescribed. A trial among Canadian breast cancer patients with bone metastases treated by bisphosphonates but without comorbid conditions showed that 10,000 iu/d of vitamin D3 over a four-month period had no adverse effects (Amir et al., 2010). Thus, from the literature, one may suggest that taking 10,000 iu/d for a month is effective in rapidly increasing the circulating levels of 25(OH)D into the preferred range of 40–60 ng/ml.

To maintain optimal level of vitamin D3 after that first month, the dose can be decreased to 5000 iu/d (Shirvani et al., 2019). But we must consider that according to the risk of hypercalcemia in high doses of vitamin D prescription, calcium supplementation should not be high. A recent review proposed using vitamin D loading doses of 200,000–300,000 iu in 50,000-iu capsules to reduce the risk and severity of COVID-19 (Gasmi et al., 2020).

Many countries proposed that the optimal goals of 20 ng/ml (50 nmol/l) are adequate. According to the statement by European Society for Clinical and Economic Aspects of Osteoporosis, Osteoarthritis, and Musculoskeletal Diseases, “attainment of serum 25(OH)D levels well above the threshold desired for bone health cannot be recommended based on current evidence, since safety has yet to be confirmed” (Cianferotti et al., 2017). However, this statement, published in 2017, is no longer correct since a number of vitamin D supplementation studies reported that long-term vitamin D supplementation had health benefits without adverse health effects, e.g., 2000 iu/d for cancer risk reduction and 4000 iu/d for reduced progression from pre diabetes to diabetes (Pittas et al., 2019).

Recommendations in COVID-19 pandemic status

A recent review on vitamin D primary goals in vitamin D deficiency treatment reported that “a 25(OH)D level of > 50 nmol/l or 20 ng/ml is the primary treatment goal, although some data suggest a benefit for a higher threshold (Grant and Garland, 2002). As another article noted “although 20 ng/ml seems adequate to reduce the risk of skeletal problems and acute respiratory syndromes, concentrations above 30 ng/ml have been associated with reduced risk of cancer, type 2 diabetes mellitus, as well as adverse pregnancy and birth outcomes (Grant et al., 2020b). However, based on several studies that provided some recommendations for breast and colorectal cancer prevention (Garland et al., 2009), the desirable concentration should be at least 40–60 ng/ml.

In 2011, the Endocrine Society recommended supplementation of 1000–4000 iu/d of vitamin D and a serum 25(OH)D concentration of 30 ng/ml or higher in this area (Holick et al., 2011). These guidelines addressed all chronic disease patients. The United State Institute of Medicine showed no adverse effects of vitamin D supplementation in daily doses of < 10,000 iu/d (Ross et al., 2011).

Measuring serum 25(OH)D concentration is useful to determine the baseline and achieved 25(OH)D concentrations goals specially in some sub groups that need higher doses to achieve optimal goals, such as pregnant women, the obese, people with chronic diseases, and the elderly (Grant et al., 2020b).

In addition, some factors increase 25(OH)D concentration during vitamin D supplementation, including genetics, digestive system health, weight, and the baseline 25(OH)D concentration.

The 25(OH)D concentration increased to 40 ng/ml and 6235–7248 iu/d in about half of the people who used 5000 iu/d of vitamin D3 or 30,000–35,000 iu/wk, ensuring that 97.5% of the
people had concentrations > 20 ng/ml (Veugelers et al., 2015) that did not exceed the 10,000 iu/d threshold. However, vitamin D fortification of the basic foods such as dairy and flour products (Grant and Boucher, 2019) can raise the serum 25(OH)D concentrations up to a few ng/ml (Camargo et al., 2012, Martineau et al., 2017). To reach more benefits, daily or weekly vitamin D supplementation is recommended (Martineau et al., 2017) based on the annual measurement of serum 25(OH)D concentration for those with health risks evaluations (Grant et al., 2020b).

Magnesium supplementation in the range of 250–500 mg/d is also recommended during vitamin D supplement therapy. Magnesium, as a cofactor in the enzymatic reactions of the liver and kidneys, activates vitamin D and regulates calcium and phosphate homeostasis to influence the growth and maintenance of the bones (Uwitonze and Razzaque, 2018).

A recent review concluded that despite contradictions, available evidences show that supplementation with multiple micronutrients plays immune-supporting roles that modulate the immune function and reduce the risk of infection. In this vein, micronutrients such as vitamins C and D and zinc have the strongest evidence for immune support are (Gombart et al., 2020).

The hypothesis that vitamin D supplementation can reduce the risk of influenza, COVID-19 risk, and mortality should be studied in trials to propose safety, efficacy, the optimal doses, and serum 25(OH)D concentrations (Han et al., 2016).

References


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