Vitamin D Deficiency and Falls in Older Adults

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A master’s project submitted in partial fulfillment of the requirements for the degree of

MASTERS OF NURSING

Washington State University
College of Nursing

December 2010
To the Faculty of Washington State University:

The members of the committee appointed to examine the scholarly project of DEBRA LYNN FULLER and find it satisfactory and recommend that it be accepted.

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Vitamin D Deficiency and Falls in Older Adults

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Submitting Manuscript to: Journal of the American Academy of Nurse Practitioners

Abstract

Community dwelling older adults living independently in their homes commonly are found to be vitamin D deficient (Venning, 2005). The older adult population over age 60 comprises a group with increased risk for deficiency due to co-morbid conditions, as well as decreased intake of vitamin D and lack of exposure to sunlight. Vitamin D deficiency has been described as being essential for multiple body functions, including muscle stability, strength and balance. The purpose of this literature review was to evaluate the clinical, humanistic, and economic outcomes of vitamin D supplementation in older adults. Available research demonstrated not only a correlation between falls and vitamin D deficiency, but also that falls can be reduced with supplementation and normalization of serum vitamin D levels. Falls result in fractures leading to hospitalizations, increased health care costs, and ultimately loss of independence for older adults. Thus, appropriate assessment, supplementation, and monitoring to optimize serum D_3_ levels in older adults can contribute to reducing the morbidity, mortality and health care costs associated with falls in the older adult population.
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Vitamin D Deficiency and Falls in Older Adults

Adults over age 60 are commonly found to be vitamin D deficient (Venning, 2005), and deficiency has been associated with falls and fractures leading to adverse outcomes and loss of independence (Holick, 2007). According to estimates, over 1 billion people worldwide are vitamin D deficient. For the older population in the United States, 40 to 100% living independently are vitamin D deficient (Holick, 2007). Older adults are at increased risk for deficiency due to often having other co-morbid conditions and generally receiving less sunlight than younger populations. Older adults are often being treated for chronic conditions, and may take medications such as thiazide diuretics, corticosteroids, warfarin, anticonvulsants, and some cholesterol-lowering agents that can prevent vitamin D absorption from the gastrointestinal tract (Syroney & Franjesvec, 2010). Because it is difficult to consume adequate amounts of vitamin D by normal dietary intake alone, supplementation is likely essential for older adults to maintain optimal vitamin D levels. Without vitamin D, minimal calcium and phosphorus absorption occurs, putting the deficient population at increased risk for fractures should falls occur. In the 65 and older population, falls make up the largest single cause of morbidity and mortality. It is estimated that 35-40% of older adults fall annually (Bischoff-Ferrari et al., 2004; Masud & Morris, 2001), as compared to 12% in men and women ages 45 who fall (Hoidrup, Sorensen, Gronback, & Schroll, 2003). It is also estimated that 5% of the population with falls will experience a fracture, and 1% will experience a hip fracture (Weatherall, 2004). Vitamin D supplementation has demonstrated improved balance and muscle mass, as well as a reduction of falls in older adults (Dawson-Hughes et al., 2005). The purpose of this paper is to evaluate available research regarding vitamin D acquisition and types of vitamin D supplementation,
classification of serum vitamin D levels, the link between vitamin D levels and falls, the safety and effectiveness of varying doses of vitamin D supplementation, and finally, based on the above data, implications for practice will be delineated using the framework of the Economic Clinical and Humanistic Outcomes (ECHO) Model.

The Economic, Clinical, and Humanistic Outcomes Model (ECHO) provides a framework for evaluating pharmacotherapeutic and other clinical interventions (Kozma, Reeder, & Schulz, 1993). The model takes into account the effectiveness of the intervention (clinical aspect of the model), patient satisfaction and adherence (humanistic aspect of the model), as well as the consequences and costs of alternative treatments (economic aspects of the model) to examine the relative value of health care intervention. In summary, the model provides a basis for considering allocation of health care resources while taking into account the economic, clinical, and humanistic benefits, risks, and outcomes of a given intervention (Kozma, Reeder, & Schulz, 1993).

**Literature Review**

A comprehensive literature search of research published between 2001 and 2010 was conducted using PubMed, Medline, CINAHL, and Cochrane Library databases. Additionally, internet searches of the CDC, World Health Organization and Google Scholar web sites were conducted. Key words used in the search included: vitamin D deficiency, vitamin deficiency elderly, vitamin deficiency fractures, elderly falls, adult falls, vitamin D toxicity, optimal vitamin D, ergocalciferol, cholecalciferol, and prevention of falls, all of which were used in various order and combination during the search. The inclusion criterion for this literature review was: adult subjects 60 years and older, primary research pertaining to vitamin D₃ (cholecalciferol), muscle
strength and fall evaluation with treatment of vitamin D₃, and journals written in English. A total of 47 articles were reviewed, of which 32 were utilized after meeting inclusion criteria for this literature review. The references of articles obtained were also reviewed to identify primary research that met the inclusion criteria. After inclusion of this step, the final number of research articles included in this literature review was 12.

**Vitamin D Acquisition and Supplement Types**

Vitamin D was misclassified as a vitamin in 1922. It is actually a steroid hormone produced in the body after exposure to ultraviolet B radiation from sunlight. Sunlight is one of three ways to obtain adequate amounts of Vitamin D, and is the simplest way to obtain vitamin D. Vitamin D is produced endogenously when solar ultraviolet B (UV-B) rays penetrate the skin and convert 7-dehydrocholesterol in the skin to pre-vitamin D₃, which is subsequently converted to vitamin D₃ for use by the body (Shroff, Knott, & Rees, 2010). The amount of sunlight needed for the body to produce adequate amounts of vitamin D₃ is from 5-30 minutes, with exposure of face, arms, and legs at least twice a week (Higdon, 2004; Holick, 2007). Estimates indicate that this amount of sunlight in the summer months between 10 am and 2 pm can produce up to 20,000 IU of vitamin D within 24 hours (Holick, 2007; Shroff, Knott, & Rees, 2010). Factors that can affect the body’s ability to metabolize sunlight to vitamin D₃ include season of the year, geographic latitude (above 40 degrees north latitude), time of day, cloud cover, smog, clothing, skin melanin content, and sunscreen use. Use of sunscreen with a sun protection factor, as low as 8 can cut synthesis by 95% ("Dietary supplement fact sheet: vitamin D," 2010). Vitamin D intake through sun exposure cannot lead to toxic levels of vitamin D. Excessive sun exposure degrades pre-vitamin D and leads to the conversion of pre-vitamin D to lumisterol and
tachysterol (Mosekilde, 2005). After being converted to these substances, the ability to bind to the vitamin D is halted, and the substances get sloughed off with normal skin turnover (Holick, 2007).

Diet is the second way to obtain vitamin D, but it is difficult to consume sufficient amounts through normal dietary intake. Vitamin D is a fat-soluble vitamin that is present naturally in very few foods (Brannon, Yetley, Bailey, & Picciano, 2008). It is highest in fatty fish such as salmon, and lowest in animal meats. Foods occurring naturally that are high in vitamin D include such items as a teaspoon of cod liver oil that provides 1,360 IU vitamin D, a 3-ounce serving of sockeye salmon that provides 794 IU, and a 3-ounce serving of mackerel that contains 388 IU. Foods such as milk, grains and cereals currently are minimally fortified by manufacturers with vitamin D. For instance, an 8 ounce glass of fortified milk contains 100 IU of vitamin D ("Dietary supplement fact sheet: vitamin D," 2010). Interestingly, despite the fact that only minimal amounts of vitamin D are added to certain foods, fortification is the major source of vitamin D intake in the United States (Brannon, Yetley, Bailey, & Picciano, 2008). It is estimated that the population as a whole has a total daily intake of 200 IU of vitamin D from foods, with current recommended daily allowance of 400 IU (Fosnight, Zafirau, & Hazelett, 2008). Thus, it is not surprising that older adults who are not exposed to much sunlight are vitamin D deficient.

The third method of attaining vitamin D is through supplementation (Holick, 2007). Recommended daily allowances for vitamin D were established in 1997, and included recommending adults ages 51-70 supplement with 400 international units (IU) daily, and adults ages 71 and older supplement with 600 IU of vitamin D daily (Higdon, 2004). Dietary guidelines established in 1997 by the Food and Nutrition board have not been reevaluated or
updated since the initial recommendation. The board is in the process of reviewing the guidelines, but currently the National Institute of Health for dietary guidelines defines the safe upper limit for supplementation to be no more than 2000 IU daily to avoid adverse effects ("Dietary reference intake for vitamins," 2010)

As a supplement vitamin D is available in 2 forms, cholecalciferol (D₃) obtained from sun exposure and fish consumption, and ergocalciferol (D₂) as a plant derived form (Houghton & Vieth, 2006). Glendenning et al. (2006) recruited vitamin D-insufficient inpatients who had hip fractures and serum 25-hydroxyvitamin D [25(OH)D], levels less than 50 nmol/L to evaluate the effectiveness of the two types of vitamin D. The researchers utilized a block randomized, double-blind trial with cholecalciferol 1000 IU per day and ergocalciferol 1000 IU per day for three months. Results demonstrated the cholecalciferol group (D₃) had a 31% greater increase in serum 25(OH)D level, than the ergocalciferol group. The cholecalciferol group’s 25(OH)D increased from 42 at baseline to 79 nmol/L at study end, whereas the ergocalciferol (D₂) group’s levels increased from 37 to 57 nmol/L of 25(OH)D. Study findings demonstrated that cholecalciferol, vitamin D₃, is more effective at raising serum 25(OH)D levels as compared to vitamin D₂ (Glendenning, et al., 2006).

Another study by Armas, Hollis, and Heaney (2004) evaluated the effectiveness ergocalciferol (D₂) and cholecalciferol (D₃) and concluded that cholecalciferol raises and maintains serum 25(OH)D levels to a greater degree. The study was conducted with random assignment of thirty participants ages 20 to 60, to three groups to include a control group that received no supplement, and the two remaining groups who would receive a one time dose of ergocalciferol 50,000 IU, or cholecalciferol 50,000 IU. In this 28 day study, evaluation of serum 25(OH)D levels were obtained at baseline, then after the one time dose on days 1, 3, 5-7, 14 and
28. It was noted that both ergocalciferol (D<sub>2</sub>) and cholecalciferol (D<sub>3</sub>) produced initial rises during the first 3 days, but the serum levels of participants who received the ergocalciferol began to fall, and by day 14 had returned to baseline. The serum 25(OH)D levels of participants that received cholecalciferol (D<sub>3</sub>) continued to rise through day 14, and by the study end on day 28, their serum levels were still higher than the peak level achieved by the participants that received ergocalciferol. From this study it can be concluded that cholecalciferol, vitamin D<sub>3</sub>, raises and sustains serum 25(OH)D levels to a more substantial degree than ergocalciferol (Armas, Hollis, & Heaney, 2004).

Classification of ‘Normal’ Serum Vitamin D Levels

Vitamin D levels are measured by serum 25-hydroxyvitamin D [25(OH)D], and the optimal level for health promotion and maintenance have been under continual debate. Vitamin D deficiency is defined by most as a serum 25-hydroxyvitamin D level of less than 20 nanograms per milliliter (ng/ml), or less than 50 nanomole per liter (nmole/L) (Fosnight, Zafirau, & Hazelett, 2008; Holick, 2007). Another reference referred to deficiency in stages varying from mild to severe, using 10-20 ng/ml as mild, 5-10 ng/ml as moderate, and <5 ng/ml as severe (Boonen et al., 2006). The two reference values noted by labs can easily be converted by multiplying the result in ng/ml by 2.5 to obtain nmol/L. It is felt desirable for maximal benefit, to maintain a serum level of >75 nmol/L or >30 ng/ml, because it is at this level that the PTH is suppressed (Vieth, Chan, & Macfarlane, 2001). Toxic levels are considered when serum levels are >200 ng/ml or >500 nmol/L (“Dietary supplement fact sheet: vitamin D,” 2010).

Evaluation the serum parathyroid hormone (PTH) level is a useful indicator of vitamin D status. Elevated concentrations are often an indicator of vitamin D deficiency. Boonen et al.
(2006) described an observed vitamin D level of between 50 and 80 nmol/L, as being the range at which PTH is suppressed. Suppression of PTH is seen as beneficial for bone health due to decreased bone turnover (Vieth, Chan, & Macfarlane, 2001). Calcium is more readily absorbed in the body at higher serum vitamin D levels of 85 than at 50 nmol/L (Boonen et al., 2006). Physical inactivity which can cause bone turnover and serum calcium levels to increase, can prevent an elevation in serum parathyroid hormone even when vitamin D deficiency is present (Janssen, Samson, & Verhaar, 2002).

Shroff, Knott, and Rees (2010) emphasized the need for circulating 25(OH)D levels to be maintained between 40-80 ng/ml. Normal serum 25(OH)D levels of individuals living close to the equator are typically greater than 40 ng/ml. Shroff and colleagues suggest that keeping serum vitamin D within this level better ensures a normal calcium level, as well as preventing stimulation of the PTH. Calcium has been shown to have increased absorption in the intestine by up to 65%, when serum 25(OH)D levels were increased from deficiency state of 20 to 32 ng/ml (Shroff, Knott, & Rees, 2010).

Mocanu et al. (2009) also demonstrated the benefit of a daily dose of 5000 IU vitamin D, and calcium 800 mg in a study that involved 45 nursing home residents. The supplementation was accomplished by fortifying bread with 5000 IU vitamin D and 800 mg calcium. The researchers’ goal was to maintain a serum 25(OH)D level of > 75 nmol/L and elicit suppression of the PTH and bone-turnover markers. Results demonstrated an increase in mean serum 25(OH)D from 28 at baseline to 126 nmol/L at 12 months. There were no changes in serum calcium or hypercalcemia observed during the study or during post study follow-up. Fortification at this dose produced no evident adverse effects on the participants, providing reassurance of the safety of vitamin D at the dose of 5000 IU (Mocanu et al., 2009).
Vitamin D Dosing

Vieth, Chan, and Macfarlane (2001) researched the safety of using vitamin D in doses higher than the upper recommended limit set by the National Institute of Health of 2000 IU per day. The researchers also sought to demonstrate the amount of supplementation necessary to reach the goal of >75-100 nmol/L, which is the level felt necessary by many to prevent falls and provide optimal bone health. This study utilized healthy volunteers (N=61) consisting of men and women with mean age of 40 years to evaluate serum levels attained with the use of 1000 IU and 4000 IU vitamin D daily. The study was performed at 43 degrees latitude, and doses were randomly assigned. The study was started in the winter months, commencing in January with duration of five months. Evaluation of serum calcium, phosphate, creatinine, 25(OH)D levels, and urinary calcium were obtained at baseline, as well as monthly for the remainder of the study. Results demonstrated a mean winter serum 25(OH)D level of 40 nmol/L prior to supplementation, with 10 individuals in the < 25 nmol/L range. The results of supplementation were noted to peak by month 3 and remained stable for the remainder of the study with mean levels of 68 nmol/L in the 1000 IU group, and mean levels of 96 in the 4000 IU group. Serum calcium, phosphate, creatinine, and urinary calcium remained normal in the reference range without any significant change from baseline (Vieth, Chan, & Macfarlane, 2001). The study findings demonstrated that doses of up to 4000 IU of vitamin D per day are safe and necessary to achieve levels of serum D₃, i.e., >75nmol/L, that are associated with preventing falls maintaining optimal bone health.

Mocanu et al. (2009) conducted a study with a single arm design, using vitamin D (5000 IU) and calcium (800 mg) fortified bread. The sample involved 45 nursing home residents
during the year-long study. The primary purpose of the study was to demonstrate the safety and efficacy of food fortification. Secondary study aims included determining whether consumption of the fortified bread would increase serum vitamin D to \( >75 \text{ nmol/L} \), elicit suppression of the PTH and bone-turnover markers, and effect bone mineral density. Study findings included: 1) mean serum 25(OH)D rose from 28 at baseline to 126 nmol/L at 12 months; 2) hip bone density increased by 23%; 3) mean serum calcium levels did not change, nor was hypercalcemia observed in any participant. The findings of the study identify that doses of up to 5000 IU of vitamin D are safe and efficacious in an older adult population (Mocanu et al., 2009).

In summary, available research indicates that vitamin D\(_3\) (cholecalciferol) is more effective in raising 25(OH)D levels than vitamin D\(_2\) (ergocalciferol), that the normal range for 25(OH)D is at least 20 nmol/L, but optimal may be over 70 nmol/L, and that dosing of up to 5000 IU of vitamin D\(_3\) daily is safe. Thus, vitamin D\(_3\) supplementation appears to be a clinically effective treatment when vitamin D levels are less than optimal or deficient.

**Muscle Function with Vitamin D Supplementation**

Pfeifer et al. (2009) demonstrated the relationship between improved muscle function, as well as decreased falls with use of Vitamin D\(_3\) and calcium supplementation. The 20-month longitudinal study was conducted in Germany, latitude 52°, and Austria, latitude 46°, and involved 242 community-dwelling seniors with a mean age of 77 years. During the first 12 months, the randomized double-blind clinical trial compared the effect of supplementation with 1000 mg (milligrams) of calcium as compared to 1000 mg of calcium plus 800 IU of vitamin D. During the final 8 months of the study, supplementation was stopped in both groups, while researchers continued to gather data. Baseline, 12 months, and 20 months assessment of serum
25-hydroxyvitamin D and PTH were performed. Body sway measurements, Timed Up and Go Test (TUG), left leg extensor strength measurement, as well as falls were evaluated during this study. By month 12, a 27% reduction in falls in the vitamin D plus calcium group was noted. The analysis demonstrated a 39% reduction in falls by month 20 compared to the calcium alone group (p <0.01). The TUG test showed significant improvement in the vitamin D/calcium group as compared to calcium only (p<0.001), as well as muscle strength being significantly improved in the vitamin D/calcium group. Quadriceps strength in the left leg was significantly higher in the calcium/vitamin D group when compared to baseline (p<0.001) or the calcium only group (p<0.01). Body sway measurements in the vitamin D/calcium group did not show any improvements by month 12, but by the end of study, the calcium/vitamin D group demonstrated marked improvement in body sway (p<0.001). Serum 25-hydroxyvitamin D level at 12 months reached 84 nmol/L. In summary, the study findings demonstrated a significant improvement in the vitamin D supplemented group, noting improved muscle strength and decreased falls (Pfeifer et al., 2009).

Bunout et al. (2006) studied the effects of resistance training and vitamin D supplementation. The research was conducted in Santiago, Chile, latitude 35°, and included 96 participants with a mean age of 74 years who met inclusion criteria of having a serum 25(OH)D level of 16 ng/ml or less. Participants were randomly assigned into control and training groups. Participants in the two groups were then randomly assigned to receive 800 mg of calcium daily, or 800 mg calcium plus 400 IU of vitamin D daily. Measurements were obtained at baseline and 9 months and included bone mineral density, hand grip strength, quadriceps strength, endurance, Timed Up and Go test (TUG), body sway, and fasting serum insulin, thyroid stimulating hormone, PTH, and 25-hydroxy vitamin D [25-(OH)D]. Results at 9 months demonstrated a
twofold increase in the serum 25(OH)D level for participants who received the calcium and vitamin D. Baseline serum 25(OH)D levels were 12 ng/ml and rose to 25 ng/ml (p<0.001) at 9 months. In contrast, there was no increase in serum 25(OH)D levels in the participants that received only calcium. Participants in the calcium and vitamin D supplement group improved significantly in TUG test scores, quadriceps strength, and increased femoral neck bone mineral density 1.14±0.56% as compared to the control and calcium only groups1.08±0.55%(p=0.006). Gait speed was higher in the vitamin D groups despite training, compared to the non-supplemented groups(p=0.02). Training did improve participants’ strength, but the vitamin D plus calcium group also realized improvements in bone mass, body sway, gait speed and TUG test (Bunoutet al., 2006). This study is important, because it involved participants that had known vitamin D deficiency at baseline and showed increases to only a mean of 25 ng/ml—a level generally considered ‘normal’, but not ‘optimal’ for this group. Despite the increase of 25(OH)D to only a mean of 25 ng/ml, the findings demonstrated that vitamin D plus calcium supplementation results in improved bone mass, balance and muscle function in the older adult participants. Thus, the findings of this study, support the beneficial effects of vitamin D supplementation.

Wicherts et al. (2007) investigated the association between serum 25(OH)D levels and physical performance in older adults with a mean age of 75. The results reported were based on a cross-sectional and longitudinal design (3 year follow-up) within the Longitudinal Aging Study Amsterdam. Physical performance was assessed by performance tests that evaluated coordination, proximal muscle strength and balance. Results from the study demonstrated physical performance was poorer in individuals with a serum 25(OH)D level <10 ng/ml [regression coefficient (B) = -1.69; 95% confidence interval (CI) = -2.28; -1.10], and with a
serum level of 10 -20 ng/ml [B= -0.46; 95% CI = -0.90; -0.03] as compared to individuals with a serum level of 30 ng/ml (Wicherts et al., 2007).

**Evaluation of Falls with Vitamin D Supplementation**

Broe et al. (2007) attempted to determine the optimal vitamin D dosing necessary to reduce falls. The double-blind, placebo-controlled randomized trial was 5-months in duration and included 124 participants with a mean age of 89 years. The doses of vitamin D evaluated were 200 IU, 400 IU, 600 IU, and 800 IU. Serum 25(OH)D levels were evaluated at baseline, with a mean of 19.5 ng/ml, and again at end of study. The researchers reported that during the 5-month study, 44% of the participants in the placebo group experienced a fall. In comparison, the vitamin D supplement groups had the following proportion of falls: 58% of the 200 IU group, 60% of the 400 IU group, 60% of the 600 IU group, and 20% of the 800 IU group. The final mean serum 25(OH)D levels of the 800 IU group was 29 ng/ml. Researchers further compared the 800 IU group with the remaining groups based on the observation that there was no clear dose response across the supplement groups. The risk of falling was compared with the other four groups and there was a 71% lower fall rate in the 800 IU group (adjusted hazard ratio=.029, 95% confidence interval (CI)=0.11-0.72). The dose related response was significant in this study, supporting not only supplementation, but that a dose of at least 800 IU of vitamin D is necessary to reduce falls among older adults (Broe et al., 2007).

Flicker et al. (2005) utilized a randomized placebo-controlled double-blind trial lasting two years in duration with a 133 day follow-up, involving 625 residents in an assisted living facility, with a mean age of 83 years. The study evaluated the use of vitamin D as it relates to falls utilizing logistical regression, and Cox proportional hazard and binomial models. Inclusion
criteria included a serum 25(OH)D baseline level of 25-90 nmol/L. Each participant received 600 mg calcium, and participants were randomized to receive 1000 IU vitamin D or placebo. The results indicated a substantial decrease in falls in the group receiving vitamin D verses placebo. There were 570 falls in 451 person-years in the vitamin D-supplemented group, compared to the placebo group that had 862 falls in 453 person-years. The negative binomial model revealed a moderate reduction in the incident rate ratio for falls with treatment (0.63, 95% CI = 0.50-0.99). The study findings supported the use of vitamin D supplementation in conjunction with calcium in older adults. Those receiving vitamin D, in addition to calcium had fewer falls, however a limitation of this study was that no serum 25(OH)D levels were obtained from participants at study end (Flicker et al., 2005).

Kalyani et al. (2010) concluded from a meta-analysis of 10 studies that there is evidence to demonstrate that the use of vitamin D has a preventative effect for falls. The article described the effects of lack of vitamin D related to muscle fibers. Muscle biopsies showed atrophy of type II fibers, which are the first to be utilized to prevent a fall. The research demonstrated 14% fewer falls with use of a dose of 800 IU or greater daily. The meta-analysis included populations greater than 60 years, with mean ages of 80 (Kalyani et al., 2010).

Snijder et al. (2006) investigated the association between falls and serum 25(OH)D levels. The design was a prospective cohort study, using a random sample of 1231 community dwelling men and women, ages 55-85 years with the study duration of one year. Baseline characteristics were stratified for number of falls, age, serum 25(OH)D levels, PTH, body mass index (BMI), chronic diseases, and physical performance. Results from the study concluded that very low vitamin D levels of less than 10 ng/ml had a 11.3% higher incidence of falls (Snijder et al., 2006).
In summary, available research indicates muscle function is clinically improved with the use of vitamin D, as well as demonstrating a decrease in falls. Additionally, preventing falls reduces morbidity, mortality and costs thus contributes positively towards the economic outcome. Older adults are encouraged to continue living independent lifestyles, avoiding falls, fractures and ultimately institutionalization, contributing to a positive humanistic outcome as well. The research presented provides evidence of the clinical, economic and humanistic usefulness and effectiveness of vitamin D supplementation.

Vitamin D Safety

The daily dietary recommended intake for adults ages 50-70 is 400 IU vitamin D₃. However, the research reviewed in this manuscript indicates that up to 5000 IU of vitamin D₃ daily is well tolerated without untoward effects. Because there has been minimal research to define the upper limits, there has not been a change in the recommendations for limits since 1997. No research evaluating vitamin D toxicity was identified in the literature, but case studies have been documented.

Case studies demonstrate extremely large amounts of vitamin D need to be consumed to have deleterious effects on individuals. A 43-year old consumed daily doses of 156,000 to 2,604,000 IU of vitamin D₃ over a two-year period as a supplement. He was hospitalized due to symptoms of hypercalcemia and found to have a serum 25(OH)D level of 487 ng/L or 1220nmol/L, with normal levels between 22 to 135nmol/L (Koutkia, Chen, & Holick, 2001).

Another case study described a 58-year-old woman who was taking vitamin D, as a dietary supplement. Within 2 months of unintentional daily dosing of 188,400 IU of vitamin D₃, she was hospitalized with fatigue, back pain, forgetfulness, hypoglycemia, nausea and vomiting.
Her serum level of 25(OH)D was 468ng/ml, or 1171nmol/L. Her intended dose 400 IU, had been mislabeled by the manufacturer (Klontz & Acheson, 2007).

Research reviewed not only found supplementation with vitamin D safe and efficacious, but also a safe treatment with few or no side effects when taken at doses that are within the usual recommended doses. Vitamin D₃ was found to be a useful clinical intervention, easily administered and cost effective promoting adherence.

**Significance for Practice**

Evidence indicates a high prevalence of serum vitamin D deficiency in older adults. Deficiency ultimately affects muscle function, which puts the older adult at a significantly higher risk for falls. Supplementation has demonstrated improved muscle strength, functional ability, improved bone density and ultimately demonstrated decreased falls, supporting the clinical, humanistic, and economic benefits. Vitamin D deficiency is a modifiable risk factor in all populations, especially older adults, and deficiency can be prevented with vitamin D supplementation.

A thorough assessment of symptomatology and risk factors can better guide the vitamin D screening process. Assessment should include dietary intake of vitamin D, sun exposure, fatigue, muscle aches, muscle weakness, activity level, recent falls, and signs and symptoms of malabsorptive diseases. Other indicators for screening include any family history of diabetes, cardiovascular disease or cancer. Risk factors need to be evaluated to identify the higher risk populations. Indications for screening may also include an age 60 or older, as well as anyone with the above stated symptoms or risk factors. Because the older adult population is often
difficult to assess, and more prone to muscle atrophy and weakness, evaluation of serum 25(OH)D levels may be necessary.

Vitamin D supplementation with cholecaliferol (D₃) has been demonstrated as a clinically effective intervention for fall prevention, as well as an economically feasible treatment option for preventative care and health maintenance. Screening for deficiency should be included in the basic healthcare maintenance and evaluation of older adults, such as we currently provide with mammography, DEXA scans, colonoscopies and immunizations. Supplementation is a safe inexpensive intervention to offer as a health maintenance treatment that has been clinically proven, for example 2000 IU of vitamin D₃ costs approximately fifteen dollars a year for daily dosing. Education for older adults and caregivers regarding the modifiable risk factor of vitamin D deficiency is imperative. Research reviewed has shown improved clinical outcomes with supplementation by decreasing falls, increasing muscle strength, and improving balance. Due to the economical nature of this intervention, vitamin D supplementation has been demonstrated to be beneficial with minimal to no side effects and maximal benefits. Treatment is invaluable, cost effective, and successful without major side effects.

Supplementation in the adult population 60 years and older, with 2000 IU of vitamin D₃ daily, as well as evaluation of serum 25 (OH)D levels in an attempt to preempt deficiency prior to symptomatology has been demonstrated as a clinically beneficial intervention, as well as a economically inexpensive intervention for older adult population.

Summary

A correlation has been established between vitamin D deficiencies and falls in the older adult population. Other research suggests that falls can be reduced and even prevented with
supplementation and normalization of serum vitamin D levels. Various studies have demonstrated decreased falls with mere supplementation, and others have noted improved muscle function and increased muscle strength with a serum 25(OH)D level within a range of 75-100 nmol/L. This range was demonstrated in several studies as an optimal goal, when supplementing with vitamin D. Doses that were effective in reaching this goal were dependent on baseline 25(OH)D serum levels, but typically ranged from 4000 IU to 5000 IU. Preventing falls and fractures, enhances the abilities of older adults to maintain independence. Supplementation has demonstrated improved clinical outcomes, with a positive economic outcome. Any measure that can prevent falls and fractures as well as supporting the improved clinical, economic and humanistic outcomes, should be pursued to attain the ultimate goal of health maintenance and fall prevention.

There is a need for further controlled studies to demonstrate the optimal therapeutic range of serum 25(OH)D that results in the best outcomes while avoiding toxicity. Currently, the range of 25(OH)D that is considered deficient versus normal versus optimal is under debate. Standard dosing recommendations for vitamin D₃ supplementation would promote adoption of vitamin D supplementation in clinical practice.
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