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Vitamin D, Falls and Balance Capacity Impacts in Older Adults: Update

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Abstract

Background: Falls injuries continue to contribute to numerous premature deaths as well as high disability levels, and excess morbidity rates among older adults, worldwide. But can vitamin D account for excess falls injuries among older adults? This review specifically focuses on what is known about vitamin D in the context of postural stability or balance control, both fairly consistent independent predictors of falls among older adults.

Methods and Procedures: Drawn largely from a review of current relevant English language peer reviewed research publications published over the last 10 years detailing the relationship between vitamin D levels and balance control among the elderly, as this relates to falls injuries, evidence for any emerging consensus on this controversial topic was sought. Used to conduct the search were various key word combinations including: *falls injuries and older adults, vitamin D or vitamin D deficiency* and *balance* or *postural control*. The database used predominantly to provide input into this largely descriptive assessment and narrative overview was PUBMED.

Results: The prevailing data show falls injuries currently constitute a widespread costly major impediment to successful aging and longevity for many older adults, despite numerous efforts to prevent this disabling set of events over the past two to three decades. However, no consistent association appears to exist between the variables of vitamin D, falls, and balance attributes in the older population-despite years of research, regardless of study approach, and a strong rationale for hypothesizing a clinically meaningful relationahip.

Conclusion: It is not possible to arrive at any universal recommendation concerning the value of vitamin D supplementation as regards its possible influence on balance capacity among older adults in the realm of falls prevention efforts, as has been frequently proposed. However, until more definitive research is conducted, there still appears sufficient justification for considering the screening of vulnerable aging adults for serum vitamin D levels, along with balance impairments, and intervening as required in the case of deficits in either or both of these possible falls determinants.

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Introduction

For more than 35 years, falls have been a leading cause of death among persons 65 years of age and above, both within the United States, as well as most other countries [1, 2]. In addition to their associated healthcare costs, falls injuries continue to be associated with high premature death or fatality rates among the elderly, while many previously unimpaired elders, who survive this injury, may experience post falling-associated non-fatal albeit debilitating mobility and independence losses, including those requiring placements in assisted living centers [2, 3].

Fortunately, there is currently great interest in this topic as demonstrated by the number of research articles posted on PUBMED as of February 2021 over last 5 years, which yields more than 3600 citations. Moreover, cumulative evidence from available data show that reducing the magnitude of falls injuries and their consequences is a health issue of great promise because they indicate several potentially modifiable factors that if prevented or mitigated, might significantly reduce the risk of falling and sustaining a potentially life threatening or chronically disabling injury. These factors include, but are not limited to deficient muscle strength, confusion, sensory losses, vitamin D deficiencies, and poor postural control or balance impairments [1, 3-5].

However, despite being advocated as an effective adjunct to offsetting falls risk among the elderly [6], the specific mediating influence of vitamin D, as well as that of balance capacity in this regard, topics of independent and collective study for some time [7], remains in question.

That is, despite a converging research base that implies optimal serum levels of vitamin D, believed to potentially impact muscle function, bone quality, cartilage metabolism, pain, depression, comorbid health conditions, may also be helpful in offsetting falls risk among the elderly [7-10], this idea remains a topic of contention, especially with regard to the influence of vitamin D on balance capacity in older populations

Before continuing to base public health as well as private practitioner recommendations on inconsistent research findings, it is our view that given the problems associated with falls, and their meager intervention strategies, that a current review of all salient literature may help to avoid management errors and omissions that could be highly costly to the individual as well as society.

To this end, this present review strove to access and update the available information related to the claim that an appropriate daily supplement of vitamin D or efforts to ensure optimal vitamin D serum levels via other methods may go a long way to reducing the risk of falls due to poor balance capacity among older adults. That is, the paper specifically examines salient past and recent reports that may help establish if vitamin D supplementation is likely to positively affect balance capacity among older individuals, if they present with any deficiency or insufficiency.

It was believed the issue of vitamin D in the context of balance and falling is of high import to resolve because if proved efficacious, vitamin D supplementation as warranted, is easy to administer, and adhere to, as well as economically feasible, and practical, when compared to exercise and cognitive approaches commonly employed in falls prevention efforts to improve balance control.

The Specific Themes Examined Were

1. Whether vitamin D serum levels have an impact on falls risk in the elderly.
2. Whether vitamin D serum levels impact balance capacity in older adults.
3. Whether the effect of vitamin D supplementation is more strongly evident in older adults at risk for falls and who are vitamin D deficient.
4. Whether the mechanisms that impact balance capacity are likely to be impacted favorably by the presence of adequate vitamin D in older adults.

Materials and Methods

To best address the specific topics highlighted above, and consequently whether there is support for ensuring aging adults at risk for falls and low vitamin D and balance are tested for this risk, and treated accordingly, a search was conducted for the most salient preventable falls determinants, plus current recommended approaches to falls prevention for older adults residing in the community. This was followed by

a review of the research that has attempted to establish the health associated attributes of adequate vitamin D relative to both falls and balance capacity.

To this end, data housed electronically in PUBMED, the worlds' largest health research data base, plus data housed in Google Scholar, Science Direct, Scopus, and Web of Science were sought. Key words or phrases such as *falls, vitamin D deficiency and older adults, balance, postural control and interventions* were used to locate relevant resources. Excluded from the detailed descriptive analysis were studies of subjects younger than 60 years of age, those with neurological diseases, most research studies conducted prior to 2010, and that are detailed in Muir et al. [12]. Others were excluded if they did not focus on the topic of interest, or were written in a language other than English or were not complete articles. The studies presently reviewed included observational, as well as prospective or case controlled studies, with an emphasis on those published between January 1 2016 and January 31 2021. The review is largely limited to studies conducted in health centers or the community, rather than the nursing home or residential setting as the goal was to derive implications for community dwelling older adults who wish to remain independent in their own homes.

After the available data were scrutinized the studies and their key features were described in narrative rather than in any aggregated format, given the diversity of the available research including design consistency and methodological approaches.

Key Observations

Falls Risk Factors

Among the numerous citations detailing some aspect of falls injuries and/or falls injury determinants in the older adult population that have been housed over time in the PUBMED database and others there is general agreement on several key risk factors including:

- Impairments in cognitive function and postural reflexes [13]
- Dizziness, pain, selected pain/psychoactive medications, and visual impairments [2, 14, 25]
- Vestibular and various co-morbid disorders such as diabetes [15]
- Reduced muscular strength, impaired gait, and poor balance [16, 17, 25]
- Serum vitamin D insufficiencies [18, 19]

While no one factor listed above appears to predominate, a number of review articles and stand-alone reports have demonstrated reasonable support for the role of vitamin D in balance control as well as falls risk [e.g., Korkmaz et al., [20].

Other data show vitamin D has widespread effects on many body systems, including those that affect balance and falls risk, such as physical and cognitive health correlates [21], muscle function [22, 23], muscle strength, [24, 25], chair rising time [26], and muscle mass and its contractile capacity [27]. As well, the benefits of vitamin D may extend to improved navigational performance [27], the ability to adapt favorably to postural perturbations [28], and lower extremity and physical performance indicators in the elderly [29, 30]. Conversely, data reveal balance, a strong predictor of falls in later life [31], can increase falls rates if impaired in some way [32], such as in the presence of a vitamin D deficiency.

Balance and Vitamin D

While postural as well as dynamic balance have been cited to favorably influence falls risk in the presence of adequate vitamin D combined with calcium [8], observational or cross-sectional studies conducted over the past two decades to examine support the idea that interventions to improve vitamin D status may help to optimize balance capacity, and hence reduce falls risk have yet to produce any firm consistent findings.

For example, contrary to studies depicting a relationship between vitamin D levels and various functional parameters, Mathei et al. [33] who investigated the baseline relationship between muscle function and vitamin D status among 367 frail elderly 80 years and older in a prospective study found no significant vitamin D, balance relationship. Only 12.8% of the sample had sufficient vitamin D levels, yet this did not translate into any meaningful association of balance impairment using a static tandem stance balance test. However, dividing the cohort into four

unequally sized groups based on vitamin D serum levels, wherein some had divergent gait and hand grip scores may have affected the nature of the associations examined and their observed relationships that did not concur with previous work. The sample too may not have been comparable to those of other studies as a whole, as the participants were defined as being frail and the 'oldest of the old' according to the researchers.

Conversely, Korkmaz et al. [20] who assessed the interrelationships between vitamin D serum levels, balance, falls, muscular strength, and life quality in a cohort of 46 women with postmenopausal osteoporosis and 46 healthy women, the researchers found that vitamin D does have a direct effect on balance using three different balance test approaches. After subdividing the patient group, it was shown those with serum vitamin D levels greater than 15 ng/ml had significantly better balance scores than those with vitamin D levels lower than 15 ng/ml as shown by the longer chair rise time and rise times in the group with low vitamin D levels. The authors concluded that vitamin D is necessary as well for maintaining back extensor muscle strength, lumbar range of motion, and balance in this patient subgroup.

In support of the aforementioned findings, Boersma et al. [34] who examined 145 community dwelling adults over the age of 65 with a history of at least one recent falls associated injury or episode noted their measures of postural instability assessed using a computerized virtual reality system that assessed limits of stability and centre of pressure under eyes closed on foam and visual vestibular simulation were negatively correlated with prevailing levels of vitamin D after adjusting for demographics, biochemical and anthropometric variables. It was concluded that low levels of vitamin D are associated with increases in postural instability, and that this association could also have an effect on slowing gait velocity and increasing the risk of falls.

Similarly Krause et al. [35] found the postural body sway records of 342 older individuals to be higher among those defined as being vitamin D deficient. In this cross-sectional study, falls risk was evaluated using the New York-Presbyterian Fall Risk Assessment Tool. Postural stability was assessed on a pressure plate with feet in closed stance or hip-width stance, open eyes and closed eyes. Results showed vitamin D was not an independent risk factor for falls experienced in the last 12 months, but postural body sway was higher in cases with vitamin D deficiency (<10 µg/l). The independent risk factors for increased postural sway namely, being male and performing the test in the absence of vision were additionally compromised in the face of any vitamin D deficiency.

Akdeniz et al. [36] who evaluated the association between vitamin D and risk of falling, balance, and lower extremity neuromuscular function among women aged 60 or older also found those with serum vitamin D levels greater than 50.0 nmol/l to have better balance control than those with lower values. Using an instrumentation known as Tetrax posturography, after classifying 200 women according to their vitamin D levels and stability, their data revealed a significant association to exist between the subject's serum vitamin D levels and their stability scores, as well as their lower extremity functional scores, and falling risk.

Menant et al. [31] however, found the presence of a vitamin D deficiency or insufficiency appeared to reduce their subjects leaning balance ability, but not their postural sway. The results of this study involving a sample consisting of 463 community-dwelling older men and women 70-90 years of age, of which 21 percent of the men and 44 percent of the women were classified as vitamin D deficient, showed that after controlling for age and body mass, these vitamin D levels and leaning balance scores were more strongly related in men than women. Other observations showed those subjects with deficient vitamin D levels to have weaker upper and lower limb strength, slower simple finger press and choice stepping reaction time, poorer leaning balance and slower gait speed, after controlling for age and body mass index. They had poorer executive function and visuo-spatial ability, after controlling for age and education. Vitamin D insufficiency also increased the rate of falls in men significantly.

Huang et al. [38] who assessed women ages 29-95 and where about 70.9% had a vitamin D deficiency showed no significant associations with hand-grip strength and balance ability after adjusting

for confounding factors. Hand-grip strength and balance ability decreased with age, but vitamin D level was not a factor. Yet, according to study by Pfeiffer et al. [42] where the overall hypothesis tested was that trunk muscle strength, body sway and hypovitaminosis D would influence daily activities and the likelihood of falls and fractures, the authors did find there were significant associations between the body sway measures and vitamin D, as well as between body sway and falls, body sway and rib fractures. The authors, who examined 237 women mean age 62.9 years with osteoporosis, and measured trunk muscle strength, body sway, and the patient's falls history suggested that hypovitaminosis D is associated with increases in body sway and an elevated risk for falls and falls-related fractures.

As per von Berens et al. [39] who examined the potential association between serum vitamin D and the performance and sub-components of five repeated chair stands test, 4 meters walk test and balance in older mobility-limited community-dwelling men and women the relationship between vitamin D levels and seconds to perform the chair stands did yield a quadratic relationship. That is, at vitamin D serum levels above 74 nmol/L, the high vitamin D levels appeared to be advantageous for the chair stand test, whereas for serum levels below 74 nmol/L this association was not observed. In addition, according to Vaes et al. [40] who studied 756 men and women, aged ≥ 65 years participants with vitamin D status < 50 and 50-75 nmol/ L to have significantly lower scores on the Timed Get Up and Go balance test, compared to participants with vitamin D status > 75 nmol/L.

In short, as in summary table below, more supportive studies than not prevail as regards the clinical influence of vitamin D on balance control in older adults, when applying cross-sectional observations, but no uniform conclusion or cause effect association, has been forthcoming to date among the diverse samples studied over time. Tab 1.

Intervention and Prospective Studies

In terms of controlled or prospective studies that have examined vitamin D and balance associations, Dukas et al. [22] who studied 237 participants, mean age 75.9 years who received daily vitamin D treatments found the supplementary treatment was accompanied by a significantly increased balance capacity at three months. This effect increased after six months of therapy and was accompanied by a decrease in the absolute number of fallers and falls, compared to the six months before starting the therapy. It was concluded that the supplementary treatment with alfacalcidol containing vitamin D3 was effective in improving muscle strength, and balance, and in reducing falls numbers and rates.

Bogaerts et al. [43] who compared the effect of a regular dosage versus a higher dosage of daily vitamin D 3 (880 IU vs 1600 IU) versus exercise to improve balance among 113 older institutionalized individuals randomized to a vibration exercise group or control group found dosage rates of vitamin D did not impact their measures of balance and gait differentially. Studying only healthy adults, average age 79.6 years, this group measured the subjects' dynamic balance along with their falls risk before and after six months. Results showed no differences in any outcome were predicted by the vitamin D dosages, and that there were also no differences in falls risk, regardless of exercise status, nor any postural control differences. These results by Bogaerts et al. [43] were however, not consistent with those of Annweiler et al. [28] where higher serum vitamin D concentrations were associated with better balance among older adults categorized as having supra-optimal vitamin D status. They did align however with those of Bird et al. [32] who found no association between seasonal vitamin D variations and postural sway measures in independently mobile older adults assessed prospectively.

The findings in the literature may however, depend on what is measured. For example, in a study by Iwamoto and Saito [26] designed to clarify the effect of a vitamin D derivative on body balance, these authors found no significant improvement in the unipedal standing time measure in the experimental group, compared with the control group, even though chair-rising time decreased significantly in that group compared with the control group. In this study, 106 postmenopausal women with osteoporosis, average age 70.8 years were randomized into two equal size groups: a bisphosphonate group (control group) and a bisphosphonate plus vitamin D group. Biochemical

Table 1. Table depicting variations in conclusions and samples studied in the context of the issues of vitamin D sufficiency, balance control, and falls risk in the older population in observational approaches

a	Sample	Vitamin D/Balance Association
Boersma et al. [34]	145 community dwelling adults > age 65 with history of at least 1 recent falls injury	Association prevails, whereby low vitamin D levels, are related to poorer balance
Korkmaz et al. [20]	46 women with postmenopausal osteoporosis and 46 healthy women	Association prevails
Krause et al. [35]	342 individuals, av. age 68.3 yrs	Partially supported for balance, esp. for men
Menant et al. [37]	463 community-dwelling older men + women 70-90 yrs, where 21% men and 44% women were vitamin D deficient	Partial association prevails primarily for men for vitamin D deficiency and dynamic balance
Brech et al. [41]	Post menopausal women over age 60 with osteoporosis	Partial association, vitamin D presence is positive for timed get up and go test, not related to postural control test
Pfeiffer et al. [42]	Osteoporotic women av. age 62.9 yrs	Association prevails
Mattei et al. [33]	367 frail elderly 80 yrs	No association
Akdeniz et l. [36]	200 women 60 yrs and above	Association prevails
Huang et al. [38]	1095 women, ages 29-95 yrs	No association
Vaes et al. [40]	756 adults older than 65 yrs, 45% vitamin D deficient	Inverse association affirmed between vitamin D status and timed balance test
Von Berens et al. [39]	610 community dwelling mobility limited men/women, av. age 77.6 yrs	Partially supported

markers, unipedal standing time-a measure of balance, and five-repetition chair-rising time (a measure of muscle power) were evaluated before and after the 6-month study period. The present study showed that although the intervention improved the chair-rising time of postmenopausal osteoporotic women treated with bisphosphonates, it had no effect on the functional balance measure.

To add to the confusion, a two year follow up study by Uusi-Rasi et al. [44] concluded vitamin D supplementation and exercise recommended for prevention of falls for older people were not efficacious, but that strength and balance training were more helpful. The cohort were all 70 years and older with a falls history. The four study groups included a placebo group without exercise, a vitamin D (800 IU/d) group without exercise, a placebo and exercise group, and a vitamin D (800 IU/d) and exercise group. The main outcome assessed monthly was reported falls. Injurious falls and the number of fallers and injured fallers were reported as secondary outcomes. As well, bone density, physical functioning (muscle strength, balance, and mobility), and vitamin D metabolism were assessed. Vitamin D maintained femoral neck bone mineral density and increased tibial trabecular density slightly, but only exercise improved muscle strength and balance. While vitamin D had no mediating exercise effect on physical functioning, those using vitamin D without exercise or exercise alone, showed evidence of lower Hazard ratios for fall injuries. However, the accuracy of monthly falls diary reports, the definition of falls applied, the nature of the 'balance' measures, the method of classifying and analyzing falls incidents, baseline serum levels all above 26 nm/ml, and the exclusion of non-injurious falls in the analysis may have influenced the outcomes observed.

As argued by Anek et al. [45], the impact of vitamin D supplementation may not only depend on what is measured in clinical trials, but may well depend on the extent of the vitamin D dosage or its mode of delivery or both among a multitude of other factors, such as type of vitamin D analog applied. For example, despite some negative findings between balance and vitamin D correlates when vitamin D3 supplementary dosages prevail [44], Anek et al. [45] showed that high supplementary doses of vitamin D2 [as opposed to D3] did yield improvements in balance ability at the post test conducted on normal stability surfaces when experimental subjects were compared with a control group. This group divided post-menopausal women into two equal size groups, 26 who received vitamin D supplementation, and 26 who served as a control group. The experimental group received 20,000 IU of vitamin D2 per week, for a period of 4 weeks. The control group did not receive vitamin D2. It was concluded that a short-term vitamin D2 supplementation period may reduce the falls risk that prevails among older women.

Similarly in a study by Cangussu et al. [46] the authors who applied vitamin D supplementation to postmenopausal women fallers found falls rates were almost 50% higher in the control group, and the relative risk for recurrent falls was 2.80 times higher for the control group compared to the experimental group. The experimental group who received the supplementation showed a reduction in body sway in both the antero-posterior and latero-lateral directions, indicating a positive independent outcome of D supplementation on postural balance after 9 months, along with a significant falls reduction rate. Cangussa et al. [46] who conducted one of the very few studies that have been designed specifically to evaluate the impact of isolated vitamin D supplementation on falls rates and postural balance among older women fallers using a double-blind, placebo controlled trial design found reductions in both these factors at 9 months. Moreover, the mean vitamin D values over the 9 months increased in the experimental, but not the control groups where they declined and where there were proportionately more falls as deduced through interviews. As well, balance parameters improved only in the supplemented group. Studied were 160 postmenopausal women, ages 50-65 years, with a history of at least one fall in the past 12 months of which 80 received vitamin D3 supplementation of 1,000 IU/day administered orally for nine months. The researchers omitted adults with neurological or musculoskeletal disorders, balance disorders, drugs that could affect balance and those with osteoporosis. The subjects' postural balance was assessed using computerized stabilometry, serum vitamin D was assessed by high performance liquid chromatography, and the numbers of falls incidents

were recorded by interviews.

The application of vitamin D to increase a vulnerable older subjects serum levels, as well as potentially impacting fall risk favorably [47], has however, been disputed quite recently as far as its possible influence on musculoskeletal health, including falls prevention by Bolland et al. [48] and Smith et al [49]. Vitamin D therapy, may also fail to prevent falls and fractures if delivered in the form of 500,000 IU of oral vitamin D ingested annually to avert declines in vitamin D exposure during the autumn and winter months in older adults who are mostly not vitamin D deficient [50]. However, Hillstrom et al. [51] who recently reported on pilot work that attempted to determine if attaining higher than recommended vitamin D levels of $\geq$ 20 ng/ml believed to foster overall health, plus bone health, and balance would in fact do so, generally found vitamin D to impact favorably on muscle function, balance, and overall muscle size of post menopausal women. Similarly Sahin Alek et al. [52] who strove to verify that vitamin D is not only associated with calcium homeostasis, but skeletal muscle health and some chronic diseases found that vitamin D replacement administered especially to their most deficient cases tended to improve their elderly subject's balance.

Levis and Gomez-Marin [53] however, found no added benefit in this regard post vitamin D supplementation of 4000IU per day for 9 months, nor in regards falls risk among older sedentary men m/ml) ages 65-90 with low vitamin D baseline levels [$\leq$ 30 nm/ml] in a randomized, double-blinded controlled trial of 130 men. Although vitamin D levels increased markedly, gait and balance did not improve in the experimental group compared to the control group.

In other research involving 68 sarcopenic patients, an 8-week intervention of branched-chain amino acids and vitamin D supplementation with low-intensity resistance training did indeed improve muscle-related outcomes in these older adults [54]. Analagous data from Smimeca et al. [55] recently showed that there is a possible clinically relevant relationship between sarcopenia (evaluated in term of fibers atrophy), vitamin D receptor protein expression and *TaqI/Cdx2/FokI* VDR genotypes in an Italian cohort of older adults with either osteoporosis or osteoarthritis. These data implied that vitamin D sufficiency or its attainment may yet have an indirect bearing on the relationship between sarcopenia measures, vitamin D receptor protein expression and *TaqI/Cdx2/FokI* VDR genotype measures, and hence on the extent to which balance control impacts falls risk.

Other data have shown that intra muscular vitamin D applications, which are not well studied, can indeed have a marked effect on balance in vitamin D deficient elderly women [56], while more recently, Susuki et al. [57] who evaluated the effects of anti-osteoporosis agents, eldecalcitol, an analog of vitamin D and alendronate, a drug for treating osteoporosis on dynamic and static postural balance in aged patients with osteoporosis in a randomized, open-label, controlled clinical trial of 124 female patients aged 65 or over with osteoporosis found the vitamin D analog to produce favorable results after 24 weeks. The primary endpoint assessed was the change in a postural balance index, adjusted composite equilibrium score of sensory organization test, wherein there was no statistically significant dynamic balance improvements that were noted over time between the two groups, static postural balance was maintained in the vitamin D group, but not in the alendronate group.

In sum, despite efforts to control for extraneous factors, and to undertake follow up studies, on an array of samples, not all researchers concur that there is an association between balance and vitamin D status in older adults that can be mobilized to explain falls risk as well as mobilized to consistently prevent or reduce falls risk [see Table 2].

Possible Mechanisms of Vitamin D Influences on Balance

As outlined in additional clinical studies related to the present topic, vitamin D supplementation may be expected to have a bearing on balance capacity by improving corticospinal neural transmission [60], gait control [21], cognitive function [61] and healing post surgery [62, 63]. As well, recent data show all analyzed human brain regions to contain some level of vitamin D [64], and implying that vitamin D appears to have a bearing on the speed of intracranial processing and cerebellar volume [65, 66]. Vertigo that could impact falls risk negatively due to its possible

Table 2. Summary of the overall conclusions reached by researchers in the field who have employed controlled and prospective follow-up studies to examine vitamin D impacts as regards balance among the elderly population

Research Group	**Vitamin D influences Balance Capacity**
Brech et al. [58]	Disagree
Dukas et al. [22]	Agree
Bogaerts et al. [43]	Disagree
Annweiler et al. [28]	Agree
Bird et al. [32]	Agree
Iwamoto and Saito [26]	Somewhat agree
Uusi-Rasi et al. [44]	Somewhat agree
Anek et al. [45]	Agree
Cangussa et al. [46]	Agree
Sahin Alek et al. [52]	Agree
Hillstrom et al. [51]	Agree
Levis and Gomez-Marin [53]	Disagree
Tellioglu et al. [56]	Agree
Susuki et al. [57]	Somewhat agree

destabilizing effects may be also be influenced by the prevailing level of vitamin D [67]. Other data show vitamin D supplementation can enhance both physical and cognitive health [59], muscle function [22, 23, 69], muscle strength, [24, 25], muscle mass, power and contractile capacity [68-70], navigational and cognitive performance [27, 71], postural control [72] postural adaptations [28], and lower extremity function in the elderly [68, 73, 74]. Falls prevention itself also continues to be demonstrated in cases that receive daily vitamin D supplementation [75] as well as bone, muscle, and nerve health [76].

Low vitamin D levels, in contrast, tend to be linked to muscle mass, strength and contractile capacity declines, poor muscle endurance capacity [77, 78] plus suboptimal physical performance ability [68]. The accuracy of motor imagery during gait [59] is also found to be reduced in the presence of insufficient serum vitamin D levels.

Discussion

Falls, which continue to increase in both incidence and prevalence, remain a widespread health concern despite years of research designed to prevent falls injuries in adults over age 65 [76]. Commonly associated with the onset or perpetuation of longstanding pain, disability, independence losses, and premature deaths for many, the outlook for older adults in this regard, remains bleak [79]. Indeed falls and their consequences, currently deemed one of the most serious major public health issues facing aging nations [80], are not only especially problematic in the case of those older adults who are frail [6] due to their high mortality and morbidity rates, but falls injuries requiring hospitalization during the COVID-19 pandemic may inadvertently place the individual at an ever than anticipated risk for mortality and excess morbidity.

Moreover, even if falls do not require hospitalization, falls that tend to constrain movement, individual freedom and confidence, while heightening sedentary behaviors, and excess falling fears, may be sufficiently injurious in their own right to warrant considerable or definitive care from health professionals or others, as well as the usage of high levels of health care resources [81-84]. At the same time targeted pharmacological management strategies to offset the risk for falling among the elderly are largely non-existent, with the exception of possible recommendations to reduce certain medications that may provoke dizziness or confusion [76, 85]. Instead, in the vast majority of cases, preventive measures in and out of the home, plus daily activity management programs are currently advocated to help the aging individual to avoid the partial or complete loss of personal freedom associated with falls, as well as excess rates of premature mortality, and morbidity [76].

These approaches commonly include but are not limited to one or more of the following:

Recommendations to carry out regular exercise such as Tai Chi balance exercises

Vitamin D Supplementation with or without Calcium

- Withdrawal of psychoactive drugs
- Depression identification and treatment
- Vision interventions
- Environmental assessments and modifications [84-86]

In this regard, and for almost two decades, the recommendation that optimal levels of vitamin D be employed as one of the multiple efforts advocated to prevent falls injuries among older adults has been discussed favorably by some [75, 87, 88], and mentioned by others [eg 4, 6, 85]. However, even though vitamin D supplementation, is emerging, as a potentially safe and well-tolerated falls prevention strategy due to its potential beneficial effects on the musculoskeletal system along with anticipated improvements in muscle strength, balance and navigational abilities [86] when applied to achieve adequate serum levels [87], the question of whether vitamin D can impact muscle-associated falls injury risk favorably in older populations or does not affect falls risk in any way [48] remains in question [89]. The negative studies that prevail in this regard [eg 90] are also contrary to recommendations for the supplementation of vitamin D where indicated to maintain musculoskeletal health in older adults [91], especially those with low vitamin D levels [92] and in the context of falls prevention efforts among the elderly [78, 93-95]. This also includes overall health status, as well as muscle endurance, muscle mass and strength, bone mineralization [95], and neuropsychological functional benefits [37]. Yet, despite being quite well grounded in a fairly strong rationale and set of contemporary studies [42, 52, 81, 94, 95], not all authors concur. Indeed, as outlined in Tables 1 and 2, even though negative or null findings are often not published, there are several non-supportive and basically unanticipated adverse findings in this regard in both the recent and past literature concerning vitamin D and balance and falls risk correlates in the elderly [96]. At the same time, as implied in other falls vitamin D reports [75, 88] some of these observed differences clearly implicate the variations in the nature of the study sample, possible gender issues, the study duration, design and its quality, nutritional status [97], vitamin D dosages [37, 49], and outcomes assessed. As well, flaws in available studies, especially the aggregation of diverse input and output variables, and the limited power to demonstrate effects that exist may be leading to these competing conclusions [98]. Moreover, the impact of medical status, vision, sleep factors, dietary factors, food intake, nutrition and falls education, and other co-intervention effects, plus variations in initial vitamin D status and vitamin D supplementation adherence rates, is often hard to tease out in studies examining falls injury risk, vitamin D and balance attributes. As well the confounding role of falls history, fear of falling, frailty, type of vitamin D analog used, genetic influences of vitamin D receptors on muscles in sarcopenic adults [99], plus mode of vitamin D administration remains relatively understudied [98]. According to Thanapleutiwong et al. [75] the results of a prior negative meta-analysis by Bolland et al. [48] may have been due to its focus on vitamin D monotherapy rather than including studies employing vitamin D analogues, plus studies which compared vitamin D plus calcium and

placebo.

Moreover, how balance is defined and measured is not standardized in any way between studies, and may include measures of perceived subjective balance perceptions, postural perturbation tests, and static balance tests often conducted indoors that may not emulate those protective responses occurring or needed in actual fall situations. Similarly, how vitamin D intake is assessed may be questionable, as may serum measures of vitamin D over differing seasons, or fluctuations in health states At the same time, balance associated assessments using the sit-to-stand timed tests are often employed differentially, sometimes representing balance capacity, at other times representing muscle power. It is also challenging to account for how vitamin D found to improve vitamin D levels in fallers with vitamin D insufficiency, is observed by some to produce more injurious results than not [48, 49, 100], for example Thanapleutiwong et al. [75] implies this might be linked to non-adherence to daily vitamin D supplementation, rather than excess vitamin D intake, but this has not been well studied. At the same time, Burt et al. [101] found no differences in balance control effects after three years, between participants who took either high, medium or low supplementary doses of vitamin D

Limitations that have been discussed as explanations for the diverse study findings in the present context, include the use of control groups that are actually receiving vitamin D_3 overtly or inadvertently, per day, rather than a placebo. As well, dose findings may end before the pre-specified thresholds for dose suspension and dose selection are reached [90]. High dose application studies also require careful investigation [eg 100] to rule out other factors for their generally discordant results. As well, the optimal approach for helping to raise vitamin D serum levels in deficient cases in the older adult population to an optimally beneficial vitamin D level has not been thoroughly examined. Similarly, other possible confounding impacts of prevailing studies that merit study are the role of outdoor vitamin D exposure, food based vitamin D components, supplements that already contain vitamin D, plus prevailing health and medication status.

In the meantime, and in light of several study outcomes implicating low vitamin D levels in balance control [eg 42, 44, 52], along with basic research to support both a rationale for validating these findings as well as a linkage to falls risk [94, 104], and/or recurrent falls [34], it is hard to accept the idea that vitamin D administered on an individualized basis [102] should be withheld from older adults who are clearly vitamin D deficient and at high risk for falling. Even if falls are not impacted, health status as well as muscular status may in fact at the very least be potentially improved [34, 95]. Moreover, given the ongoing COVID-19 pandemic and associated health care restrictions, and the fact that fallers who enter the hospital are at high risk for COVID-19 infection, more protective care in this regard appears imperative.

At the same time, researchers who desire to advance this line of research in a meaningful way might consider more careful subgroup analyses along with carefully designed single case studies, case reports, basic laboratory studies, and larger well powered clinical studies that employ more universal agreed upon standardized vitamin D classifications, clear understandings of what constitutes a fall, and balance associated measures that can serve as a proxy for falls risk. The use of more universally agreed upon objective outcome assessment procedures in studies of both short -term as well as of longer duration and that employ more sophisticated technologies to measure falls over time [102], rather than relying on interviews and surveys are strongly encouraged. As per findings of Bischoff Ferrari et al. [103], and in light of current fiscal as well as other health services constraints, dedicated efforts to define what constitutes safe efficacious vitamin D supplementation as well as unsafe levels are also highly desirable. Delineating the role of age, gender, health status, falls history, and environmental factors in this regard is also paramount and may not only greatly help to allay considerable human suffering, but the potentially highly negative consequences of referral to hospitals during COVID-19 due to falls, which seem to have increased in frequency and poor outcomes during the pandemic, rather than decreased [105].

Conclusion

Based on the severity of disability incurred, among other costs, current data clearly show that falls prevention approaches must remain a priority in the realm of fostering successful aging for all, in all countries

with aging populations. However, considerable data demonstrate inconsistent study results as to whether vitamin D, a powerful steroid serving many body functions, does or does not influence falls risk as well as balance capacity among older adults at risk for falling as is outlined in most current preventive framework recommendations. Since sufficient data support the idea that routine efforts to screen older adults for vitamin D serum levels as well as balance capacity are likely to be helpful in guiding targeted potentially efficacious falls prevention efforts in those vulnerable elderly with vitamin D insufficiencies it is recommended more research in this regard be forthcoming and should be encouraged. The promising role of vitamin D receptor influences in sarcopenic muscle, which is not well studied, should be specifically investigated in this regard.

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