The Impact of Vitamin D on Weight Loss

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Abstract

The incidence of vitamin D deficiency is increasing and 25-hydroxyvitamin D (25OHD) levels, which are inversely associated with measures of obesity, are lower in overweight and obese populations. There have been several studies that have investigated the effect of vitamin D supplementation on weight loss, and studies combining weight loss interventions with increased vitamin D intake, either through supplementation or foods fortified with vitamin D. 25OHD levels have also been measured before and after weight loss to see if they improve and if the changes in 25OHD levels are related to the degree of weight loss. Some studies have suggested that vitamin D status is associated with weight loss success, with supplementation resulting in weight loss, or higher baseline 25OHD or greater increases in 25OHD levels associated with greater weight loss, although this has not been shown in all studies.

Keywords

25OHD, weight loss, obesity, vitamin D deficiency, body composition, season

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Along with the increased prevalence of obesity, the incidence of vitamin D deficiency is rising with 10–60 % of adults having values lower than 20 ng/ml.[1,2] Serum or plasma 25-hydroxyvitamin D (25OHD) is the most widely accepted measure of vitamin D status (deficiency <20 ng/ml, insufficiency 20–29 ng/ml, and sufficiency >30 ng/ml). Many studies have shown it is inversely associated with measures of obesity and that obese participants have lower suboptimal 25OHD levels compared with healthy weight participants. Adipose tissue sequesters the fat-soluble vitamin and this leads to lower levels in obese populations. It is also thought that obese people may spend less time outdoors, or expose less skin to the sun, which may lead to reduced synthesis of vitamin D.

There has been increasing interest regarding the relationship between vitamin D, obesity, and weight loss, and this article will examine several aspects of this relationship, specifically looking at the effects of vitamin D supplementation and 25OHD levels on weight loss in adults. Possible mechanisms for the relationship between vitamin D and weight loss have been proposed.[3,4] Inadequate vitamin D status has been suggested to promote greater adiposity through the regulation of parathyroid hormone (PTH) and modulation of adipogenesis. Increased PTH, a consequence of low vitamin D levels, promotes calcium influx into adipocytes and this intracellular calcium enhances lipogenesis and inhibits catecholamine-induced lipolysis, leading to accumulation of fat and weight gain.[5,6] Achieving adequate vitamin D levels will lower PTH levels, which diminishes the calcium influx into adipocytes and increases lipolysis. 1,25-dihydroxyvitamin D, the active form of vitamin D, has also been shown to induce apoptosis in adipocytes.[7,8] It has also been suggested that lower PTH levels via an increase in vitamin D levels could lead to weight loss through a sympathetic nervous system-mediated thermogenesis and lipolysis.[3]

Does Vitamin D Supplementation Lead to Weight Loss?

Several studies have investigated the effect of vitamin D supplementation on weight loss (see *Table 1*), although all were not specifically designed to analyze this. A secondary finding from a randomized controlled trial in men with impaired glucose tolerance designed to investigate glucose and lipid metabolism found a small but significantly greater weight reduction of 1.3 % using low-dose vitamin D compared with the placebo group with no weight loss after 3 months.[9] Interestingly, 25OHD levels significantly increased in both groups, but there was a greater increase in placebo, although not reported as significant (14 % versus 39 %); consequently, it is difficult to conclude if the greater weight reduction was due to the low dose supplementation despite greater increase in placebo, which suggests a possible seasonal impact.

Following on from that study, the investigators conducted a longer uncontrolled study at a higher dose in 14 middle aged men with impaired glucose tolerance to investigate the effects on insulin sensitivity and glucose tolerance. Again, they found a small 1.1 % reduction in weight after supplementation for 18 months.[10] 25OHD levels were only measured after treatment and 6 months later so the study was unable to report if the low-dose supplementation increased 25OHD levels. Six months after supplementation 25OHD levels increased 37 %,[10] suggesting a seasonal effect, which is likely since the study started and finished in the Fall.

Table 1: Differences in Measures of Weight and Body Composition in Vitamin D Supplementation Studies

Study	nR/C	Population	Intervention	Length	Baseline 25OHD (ng/ml)	Δ Weight/Body Composition	Δ 25OHD (ng/ml)
Ljunghall et al. 1987[9]	65	Middle-aged men with IGT	0.75 µg VD or placebo (P)	3 months	VD: 37±9.4 P: 39±29	VD: –1.1 kg*^ P: –0.1 kg	VD: 5^ P: 15^
Lind et al. 1989[10]	14/10	Middle-aged men with IGT	2 µg VD (uncontrolled)	18 months		–0.9 kg	post-VD: 31±17 6 months post: 43±25
Caan et al. 2007[11]	36,282	Postmenopausal women	400 IU VD +1,000 mg Ca or placebo	7 years		Mean difference –0.13 kg*	28 % higher in VD+Ca versus P at 2 years in subset
Zhou et al. 2010[12]	870	Healthy post-menopausal women	1,400–1,500 mg Ca, Ca+1,100 IU VD or placebo	4 years	29.3±8.0	Trunk 3 year % FM; 4 year % lean VD+Ca: 1.4 %*; –1.0 %* Ca: 2.4 %*; –0.6 %* P: 5.4 %; –2.1 %	VD+Ca: –40 %* (estimated from graph) Ca and P: stable
Nagpal et al. 2009[13]	100/71	Centrally obese males	120,000 IU VD per fortnight or placebo	6 weeks	VD: 14.6±5.8 P: 12.0±5.0	Weight; WC; WHR VD: 0.03±1.82 kg; –0.4±3.83 cm; –0.01±0.03 P: –0.38±1.7 kg; –0.15±2.85 cm; –0.004±0.03	VD: 14.1±10.9 *^ P: 0.2±4.6
Wamberg et al. 2013[14]	52/43	Healthy obese adults with 25OHD <20 ng/ml	175 µg VD or placebo	26 weeks	VD:13.8±4.3 P:13.9±4.1	Weight; FM; SAT; VAT VD: 0 kg; 1.6 kg^; 0.1 L; 0 L P: 0 kg; 0.3 kg; –0.1 L; 0.1 L	VD: 30.9^* P: 5.1^
Sneve et al. 2008[15]	445/334	Overweight or obese adults	40,000 IU VD per week, 20,000 IU VD per week or placebo (all given 500 mg Ca)	12 months	21.2±6.8	Weight; WHR; % FM VD(4): 0.1 ±3.8 kg; –0.01±0.05; –0.4±1.9 % VD(2): 0.3±3.2 kg; –0.01±0.04; –0.4±1.9 % P: 0.5±3.9 kg; –0.01±0.05; –0.5±2.1 %	VD(4): 24.0±8.5* VD(2): 15.1±6.3* P: –0.9±3.8
Nilas and Christiansen 1984[16]	238	Postmenopausal women	3 trials (2,000 IU VD; 0.25 µg VD; 1 year 0.25 to 0.5 µg VD) or placebo	2 years		No change in weight when compared with placebo	
Salehpour et al. 2012[17]	85/77	Healthy overweight and obese women	25 µg VD or placebo	12 weeks	VD: 14.7±12 P: 18.8±12.8	Weight; WC; FM VD: –0.3±1.5 kg; –0.3±4.3 cm; –2.7±2.1 kg* P: –0.1±1.7 kg; 0.4±4.1 cm; –0.5±2.1kg	VD: 15.2±12.8* P: 1.8±5.6

*Values are mean ± standard deviation where available. *Significantly greater change compared with placebo; ^Significant difference between pre- and post-treatment. Δ = change; 25OHD = 25 hydroxyvitamin D; Ca = calcium; FM = fat mass; IGT = impaired glucose tolerance; nR/C = number randomized/number completed; SAT = subcutaneous adipose tissue; VAT = visceral adipose tissue; VD = vitamin D; WC = waist circumference; WHR = waist–hip ratio.*

Caan et al.[11] measured changes in weight annually for an average of 7 years in 36,282 postmenopausal women in the Women's Health Initiative clinical trial. Women who received daily vitamin D and calcium supplementation had minimal but consistent significant differences in weight compared with those taking placebo (–0.13 kg).[11] These outcomes were observed primarily in women who reported inadequate calcium intakes (<1,200 mg) or vitamin D intakes (<400 IU), with mean differences between treatment groups of –0.19 kg and –0.16 kg, respectively. 25OHD levels were only measured in 1 % of the study population 2 years after randomization and those on supplements were 28 % higher compared with those on placebo.[11] This modest difference could be explained by poor compliance with the supplementation, with the proportion consuming 80 % or more ranging 56–62 % and personal use of supplementation was allowed (up to 1,000 mg calcium and 600–1,000 IU vitamin D), which was equal or greater than the doses being investigated and may have masked any results.

In a similar study, Zhou et al.[12] followed postmenopausal women randomized to vitamin D and calcium, calcium only, or placebo supplementation to look at the effect of supplementation on fractures. After 4 years, weight decreased in the vitamin D and calcium group, was unchanged in calcium group, and increased in placebo (values not reported).[12] When looking at body composition, there was a gain in trunk fat mass and a loss of trunk lean mass, and this was greatest in the placebo group and similar in both supplemented groups.[12] This suggested vitamin D had no added benefit; however, the changes in 25OHD levels were related to changes in body mass index (BMI) and trunk fat mass ($r=-0.15$; $p<0.01$), and only those taking vitamin D and calcium supplementation had significant increases in 25OHD levels (~40 % increase) while the others remained stable.[12]

There have also been vitamin D supplementation studies that have reported no changes in weight.[13–17] All studies had significant increases in 25OHD levels following supplementation and found no changes in weight and other measures of body composition in a range of populations.[13–16] Similarly, Salehpour et al.[17] found no differences in weight and waist circumference, but they did find a greater decrease in fat mass in those treated with vitamin D compared with placebo, and this modest reduction in fat mass was inversely correlated with the increase in 25OHD levels ($r=-0.32$; $p=0.005$).

Table 2: Differences in Measures of Weight and Body Composition in Studies that Combine Weight Loss and Vitamin D Supplementation

Study	nR/C	Population	Intervention	Length	Baseline 25OHD (ng/ml)	Δ Weight/Body Composition	Δ 25OHD (ng/ml)
Major et al. 2007[18]	84/63	Overweight/obese low Ca (<800 mg)	Energy restriction with 400 IU VD+1,200 mg Ca or placebo	15 weeks		Weight; WC; FM VD+Ca: –4 kg^; –4 cm^; –3.3 kg^ P: –3 kg^; –4 cm^; –2.7 kg^	
Major et al. 2009[19]	13	Overweight/obese very low Ca (<600 mg)	Energy restriction with 400 IU VD+1,200 mg Ca or placebo	15 weeks		Weight; WC; FM VD+Ca: –5.8±2.6 kg^*; –5.6±3.3 cm; –4.7±2.3 kg^* P: –1.4±2.4 kg; –3.5±2.9 cm; –1.2±2.4 kg	
Zhu et al. 2013[20]	53/43	Overweight/obese very low Ca consumers (<600mg)	Energy restriction with 125 IU VD+600 mg Ca or no treatment	12 weeks		Weight; FM; WC; visceral FM; fat area VD+Ca: –4.1±1.8 kg^; –2.8±1.3 kg^*; –2.6±1.6 %^*; –6.3 cm^; –0.5±0.2 kg^*; –12.0±6.4 cm^2^* Control: –3.5±1.9 kg^; –1.8±1.3 kg^; –1.4±1.5 %^; –4.6 cm^; –0.3±0.2 kg^; –6.5±7.2 cm^2^	
Zittermann et al. 2009[21]	200/165	Healthy overweight adults	Weight-reduction program with 83 µg/d VD oil or placebo oil	12 months	VD: 12.0±7.0 P: 12.1±8.1	Weight; FM; WC VD: –5.7±5.8 kg^; –4.1±4.6 kg^; –6.5±9.6 cm^ P: –6.4±5.6 kg^; –4.9±4.9 kg^; –7.5±5.8 cm^	VD: 22.2±22.4^* P: 4.7±14.5^
Holecki et al. 2008[22]	40	Obese women	Weight-reduction program with 0.25 µg VD+2,000 mg Ca or placebo	3 months	VD: 25.3±13.0 P: 35.2±16.2	Weight; % FM VD: –7.0±2.6 kg^; –5.8±9.9 %^ P: –8.4±3.7 kg^; –7.0±6.0 %^	VD: 4.1±9.2 P: 3.7±8.8

*Values are mean ± standard deviation where available. *Significantly greater change compared with placebo; ^Significant difference between pre- and post-treatment. Δ = change; 25OHD = 25 hydroxyvitamin D; Ca = calcium; FM = fat mass; IGT = impaired glucose tolerance; nR/C = number randomized/number completed; P = placebo; VD = vitamin D; WC = waist circumference.*

When looking at studies that involved vitamin D supplementation without a weight loss component, there is a mixture of results. Some studies have shown minimal weight loss or prevention of weight gain, but have a range of limitations. Unfortunately, most of these studies also involved calcium supplementation or low-dose vitamin D supplementation, or study subjects could have been taking other vitamin D supplementation during the study, so it is difficult to draw conclusions from these studies as to whether vitamin D supplementation is effective for clinically significant weight loss.

Weight Loss Combined with Vitamin D and Calcium Supplementation

Studies have looked at the effect of combining weight loss strategies with vitamin D supplementation (see *Table 2*). Major et al.[18] compared vitamin D and calcium supplementation with placebo during energy restriction in overweight or obese low calcium consumers. Both groups lost a similar amount of weight, fat mass, and waist circumference; however, when looking at a subgroup of only the very low calcium consumers they found that the vitamin D and calcium group lost significantly more weight and fat mass compared with placebo.[19] Another study investigating overweight or obese very low calcium consumers undergoing energy restriction with or without a lower dose of vitamin D and calcium supplementation resulted in similar weight loss.[20] However, supplementation resulted in greater reductions in fat mass (55.6 % higher), percent fat mass, visceral fat mass, and visceral fat area.[20] While these studies have involved vitamin D supplementation, they also involved calcium supplementation and they have been more based around the calcium component, which is beyond the scope of this review. They also did not measure 25OHD levels so it is unable to determine if the dose was effective at improving vitamin D status.

Other studies have shown weight loss has not been influenced by vitamin D supplementation. Zittermann et al.[21] found similar weight loss and reductions in fat mass and waist circumference between placebo and vitamin D oil, despite 25OHD levels increasing 185 %. Holecki et al.[22] also found no difference in weight and fat loss between those supplemented with vitamin D and calcium and those with no supplementation in obese women undergoing lifestyle modification; however, this study did not find an increase in 25OHD levels, which suggests that the 0.25 µg dose was not effective.

Increases in Vitamin D Through Fortified Foods and Seasons

Studies have also looked at increasing vitamin D levels through other means, including fortified foods (see *Table 3*) and seasonal changes. Ortega and colleagues compared two hypocaloric diets: one increased cereals (enriched with vitamin D); the other increased vegetable intake for 2 weeks. Those on the cereal diet significantly increased their vitamin D intake and 25OHD levels compared with no changes in the vegetable diet.[23] While both diets lost weight and fat, those on the cereal diet had greater reductions, suggesting that greater increases in 25OHD resulted in greater losses of body fat and weight.[23,24] However, there was also a greater reduction in energy intake in cereal diet that was due to a ~1,000 kJ greater initial intake, which may also have contributed to the greater weight loss.[23] While vitamin D intake was increased, it was still suboptimal and the differences were seen over a short time-frame of only

Table 3: Differences in Measures of Weight and Body Composition in Studies that have Used Products Fortified with Vitamin D

Study	nR/C	Population	Intervention	Length	Baseline 25OHD (ng/ml)	Δ Weight/Body Composition	Δ 25OHD (ng/ml)
Ortega et al. 2009[23]	61	Overweight/ obese women	Energy restriction with increased cereals (C) (VD) or vegetables (V)	2 weeks `	C: 23.1±11.0 V: 21.8±17.3	Weight; FM C: –1.6±0.9 kg^*; –1.7±1.8 kg^* V: –0.9±0.8 kg^; –0.5±1.0 kg^	C: 4.0^ V: 2.3
Rosenblum et al. 2012[25]	171	Overweight/ obese adults	2 studies—regular orange juice (n=65) and reduced energy orange juice (n=66). Control or juice fortified with 300 IU VD D +1,050 mg Ca	16 weeks	VD: 29±11 Control: 30±13	Weight; WC; abdominal fat; SAT; VAT VD: –2.5±3.3 kg; –3.0±4.1 cm; –37.6±54.0 cm^2; –24.8±44.1 cm^2; –12.9±21.8 cm^2* C: –2.4±3.2 kg; –2.4±3.6 cm; –25.3±51.0 cm^2; 21.6±41.1 cm^2; –3.7±15.7 cm^2	VD: 3.4±13.3* Control: –3.1±12.7
Daly et al. 2009[26]	140	Men	400 ml/day reduced fat milk fortified with 800 IU VD+ 1,000 mg Ca or control (no milk)	2 years	Milk: 31.3±9.2 Control: 30.5±9.2	Milk: 0.6 kg Control: 0.1 kg	Milk: 1.9 Control: –5.8
Kukuljan et al. 2009[27]	180	Men	400 ml/day reduced fat milk fortified with 800 IU VD+ 1,000 mg Ca, exercise only, exercise+fortified milk, or control	12 months	34.5±14.4	Milk main effect Weight: 1.0 kg* FM: 0.6 kg	Milk main effect: 23.0 %*
Manios et al. 2009[28]	112/101	Postmenopausal women	Healthy lifestyle guidance+low-fat dairy products fortified with 7.5–9 μg VD+1,200 mg Ca, 600 mg Ca supplementation, or control	12 months		Weight; WC; mid-arm muscle circumference; sum of skinfolds; FM; leg FM VD: 1.4 kg; –5.5 cm; 2.2 cm*; 6.7 mm*; –0.2 %; –1.6 %* Calcium: 0.9 kg; –4.5 cm; –5.9 cm; 20.2 mm; 0.5 %; 0.9 % Control: –0.7 kg; –7.9 cm; –5.0 cm; 18.8 mm; –0.7 %; –0.9 %	

*Values are mean ± standard deviation where available. *Significantly greater change compared with placebo; ^Significant difference between pre- and post-treatment. Δ = change; 25OHD = 25 hydroxyvitamin D; Ca = calcium; FM = fat mass; IGT = impaired glucose tolerance; nR/C = number randomized/number completed; P = placebo; SAT = subcutaneous adipose tissue; VAT = visceral adipose tissue; VD = vitamin D; WC = waist circumference; WHR = waist–hip ratio.*

2 weeks. It is possible that greater improvements could be seen with a longer and higher dose supplementation.

Roseblum et al.[25] compared the findings of two studies in overweight and obese adults: one with regular orange juice; one with reduced-energy orange juice. Both studies compared regular juice to juice fortified with vitamin D and calcium. When comparing the regular to fortified juice, the fortified group had a greater than 22 % increase in 25OHD levels. There was no difference in weight loss (~3 %); however, there was a greater reduction in visceral adipose tissue in the fortified juice groups.

Several studies have investigated the effect of milk fortified with vitamin D and calcium on weight, although primarily looking at other outcomes and not in combination with a weight loss component. The fortified milk products increased 25OHD levels by 6–11 % and the nonmilk groups decreased 12–19 %.[26,27] One study found no differences in weight changes between the groups,[26] and the other found weight significantly increased by 1.0 kg in the milk group compared with the nonmilk group and there was a trend for a greater increase in fat mass of 0.6 kg.[27] The milk group in the second study also significantly increased their energy compared with no change in the other groups (+846 kJ/day), which could have impacted on the weight gain. Another study with fortified low-fat dairy products found no differences in weight change after 12 months of three dairy servings in combination with a dietary and lifestyle intervention compared with calcium supplementation and a control group.[28] However, researchers did find combining lifestyle counseling with fortified dairy products had favourable changes in some different anthropometric and body composition indices (lower decrease in mid-arm muscle circumference, lower increase in sum of skin fold thickness, greater decrease in percentage of leg fat mass, and greater increase in percent of leg lean mass).[28] 25OHD levels were not measured, so they were not able to determine if the fortified products improved vitamin D status or if it was other parts of the intervention that were having the beneficial impact. In the majority of these studies the participants were vitamin D sufficient at baseline[25–27] that, along with the low dose of vitamin D in the fortified products, could also have accounted for a modest increase in 25OHD levels. In some studies the products led to differences in energy intake that could have influenced subsequent weight loss and the products fortified with vitamin D and calcium. The dairy studies did not include a nonfortified dairy group, which again makes it difficult to distinguish between vitamin D and calcium, and also the impact of dairy, which may also affect adiposity.[29]

Different seasons are known to change 25OHD levels, with increases over summer months and decreases during winter. During a 20-week lifestyle intervention when vitamin D status improved due to seasonal change (winter to summer cohort) there were greater improvements in waist circumference compared to a cohort with reduced vitamin D status (summer to winter cohort –13.5 versus –8.4 cm, respectively).[30] The increase

Table 4: Studies that have Measured Vitamin D Levels Before and After Weight Loss and Assessed the Relationship between Changes in Body Composition and Vitamin D Levels

Study	nC	Population	Weight Loss Intervention	Length	Baseline 25OHD (ng/ml)	Δ Weight/Body Composition	Δ 25OHD (ng/ml)	Correlations
Wamberg et al. 2013[32]	17	Healthy obese adults	8 wk very low calorie diet (800 kcal) and 4 wk weight maintenance	12 wk	23.6	–12.5 kg (11.4 %)	5.2	% WL+Δ 25OHD (r=0.67; p=0.005) Δ BMI+Δ 25OHD (r=–0.67; p=0.005)
Christensen et al. 2012[33]	175	Obese knee osteoarthritis patients	8 wk 415–810 kcal/d and 8 wk 1,200 kcal/d	16 wk	19.6±8.1	8 wk: –12 kg^ 16 wk: Weight: –14 kg (13.7 %) FM: –11 kg (23.6 %)	8 wk: 6.3^ 16 wk: 6.1^	Δ weight+Δ 25OHD (r= –0.21; p=0.006) Δ FM+Δ 25OHD (r= –0.16; p=0.03)
Holecki et al. 2007[34]	43	Obese women	1,000–1,200 kcal/d+ regular exercise	3 mth	30.3±15.0	–9.6±4.9 kg (11.5±6.1 %)	2.9^	
Tzotzas et al. 2010[35]	44	Obese women	8 wk 1,000 kcal/d restriction and 12 wk additional 20 % energy restriction	20 wk	15.4±6.0	Weight; FM; WC 4 wk: –4.2 kg^; –1.2 %^; –3.7 cm^ 20 wk: –10.4 kg^; –5.1 %^; –8.7 cm^	4 wk: 1.5 20 wk: 2.9^	20 wk trend: Δ weight+Δ 25OHD (r=–0.367; p=0.065) Δ BMI+Δ 25OHD (r=–0.376; p=0.059)
Riedt et al. 2007[36]	44	Overweight premenopausal women	Energy restriction+ high or normal Ca intake or weight maintenance	6 mth	High Ca: 30.1±9.0, normal Ca: 32.5± 4.2. Maintenance: 29.8 ±10.8	High Ca: –5.9±3.0 kg Normal Ca: –4.7±1.8 kg Maintenance: –0.1±1.7 kg	6 mth: High Ca: 9.1± 23.1 %. Normal Ca: 10.6 ±22.5 %. Maintenance: 8.0±13.6 % 6 wk (n=34): high Ca: 27.9±33.4 %^, normal Ca: 26.6±40.1 %^, maintenance: –0.5±29.7 %	
Hinton et al. 2010[37]	113	Sedentary obese adults	12 wk weight loss (1,200 kcal/d and exercise) and 24 wk weight maintenance	36 wk	Women: 84.8±32.8 Men: 80.2±30.8	Weight; WL; FM; FM %. 12 wk: women: –11.0 kg (11.3±3.2 %)^; –9kg^; –4.7 %^. Men: –14.3 kg (13.0±4.2 %)^; –11.3 kg^, –7.6 %^. 36 wk: women: –12.1 kg^; –10.8 kg^; –6.3 %^. Men: –13.7 kg^; –11.8 kg^; –8.4 %^	12 wk: women: 4.1 men: 4.0 36 wk: women: –36.6^ men: –14.6^	
Mason et al. 2011[38]	439	Overweight/ obese post-menopausal women	Diet (1,200–2,000 kcal/d), exercise (45min 5xwk), diet + exercise or control	12 mth	Diet: 20.3 Exercise: 19.8 Diet+exercise: 22.0 Control: 20.5	Diet: 8.5 % Exercise: 2.4 % Diet+exercise: 10.8 % Control: 0.8 %	Diet: 2.8±3.8 Exercise: 1.7±8.6 Diet+exercise: 3.8±17.3; Control: 2.2±10.7	Δ BMI+Δ 25OHD (r=–0.23; p<0.001) Δ FM+Δ 25OHD (r=not reported; p=0.035)
Rock et al. 2012[39]	383	Overweight/ obese women	In person or telephone-based (energy reduction + exercise) or usual care	2 years	21.8±10.8	% of participants: 49.1 % gain or stable 17.5 % 5–10 % WL 33.4 % >10 % WL	Gain: –0.6±7.5 Stable: +2.3±10.0 5–10 % WL:+2.7±9.1 >10 % WL: +5.0±9.2	Δ weight+Δ 25OHD (r=–0.16; p=0.001)

Values are mean ± standard deviation where available. ^Significant difference between pre- and postweight loss. Δ = change; 25OHD = 25 hydroxyvitamin D; BMI = body mass index; Ca = calcium; FM = fat mass; mth = months; nC = number completed; WC = waist circumference; wk = weeks; WL = weight loss.

in 25OHD was associated with a greater reduction in waist circumference (r=–0.48; p<0.001).[30] Dawson-Hughes et al.[31] found the reduction in 25OHD levels due to seasonal change was attenuated by vitamin D supplementation (400 IU) in 249 healthy postmenopausal women, but found similar changes in weight, fat mass, and lean mass during these times when comparing vitamin D and placebo. While BMI was not reported, the average weight of the participants was approximately 68 kg and suggests they were not overweight so perhaps less likely to lose weight.

Do 25-Hydroxyvitamin D Levels Change with Weight Loss?

Many studies have reported lower 25OHD levels in overweight and obese populations, so it is possible they may increase with weight loss, in particular through the loss of adipose tissue, which would increase its bioavailability. Several weight loss/diet interventions have measured vitamin D before and after weight loss (see *Table 4*). Recently, Wamberg et al.[32] observed a 27 % increase in 25OHD levels after 11 % weight loss and found the relative change in 25OHD levels correlated with relative weight loss. Another study found a similar increase in 25OHD levels (31 %) following 16 weeks of dietary support (14 % weight and 24 % fat mass loss) and there was a strong correlation between change in 25OHD levels and weight loss and a smaller but still significant correlation with fat mass changes.[33] Both of these studies provided diet formula products to assist with weight loss that were enriched with vitamin D, but as they contained less than 8 μg/day, they were not likely to increase 25OHD levels to the extent seen in the studies. This suggests, along with the relationship between weight loss and changes in 25OHD, that the increases in 25OHD may be due to the weight loss.

A longitudinal study in obese women following 11.5 % weight loss found a 10 % increase in 25OHD levels.[34] While this increase in 25OHD levels was significant, it was small and likely not clinically significant and 25OHD levels remained below those of normal weight women (40.1±18.6 ng/ml). Tzotzas et al.[35] also observed a similar weight loss (10 % weight and percent fat mass loss and 9 % reduction in waist circumference) but saw a greater increase in 25OHD levels (34 %); however, the magnitude was the same (2.9 ng/ml).[35] These participants were deficient at baseline and 25OHD levels were much lower and almost half of the previous study (15.4 ng/ml). There was a trend for a relationship between weight loss and change in 25OHD. However when assessed at 4 weeks when there was small but significant 4 % weight loss, there was no change in 25OHD. The diet contained an average 221 IU per day, which is below the recommended adequate intake, suggesting it did not lead to the increase in 25OHD. These results suggest that there might be a threshold of weight loss or time needed to see a significant increase in 25OHD levels.

By contrast, another study showed the opposite picture: Riedt and colleagues[36] found no change in 25OHD levels following 7.2 % weight loss in premenopausal women. However in a subset of participants analyzed at week 6, there was a significant 27 % increase in 25OHD levels. It is likely that seasonal changes affected these findings, with the participants that were recruited in early fall having higher baseline values and smaller changes over 6 months compared with those recruited in late winter (baseline 32.9±8.2 versus 29.4±8.9 ng/ml; changes 1.1±17.9 % versus 19.8±18.2 %; respectively).[36]

There have also been studies that did not see any changes in 25OHD after weight loss. Hinton et al.[37] found no changes in 25OHD levels post-12 weeks of weight loss and, interestingly, it decreased significantly following 24 weeks of weight maintenance. The researchers found a significant season by time interaction, indicating that the change in 25OHD levels was dependent on season during enrolment and suggested seasonal variation may have had a greater impact on 25OHD than changes in weight or fat mass.[37] Mason et al.[38] investigated overweight and obese postmenopausal women undergoing three different lifestyle modification programs and a control group and found no significant changes in 25OHD levels after 12 months compared with control participants, despite significant weight loss. Interestingly, the use of personal vitamin D supplementation decreased over the 12 months, with the proportion of participants taking supplements decreasing from ~50 % to 39 %; however, the daily intake among users increased (530 IU/day to 787 IU/day) and this could have influenced the study outcomes.[38] However, what the study did find was a dose-dependent increase in 25OHD levels associated with the magnitude of weight loss, with greater weight loss having greater increase in 25OHD levels (<5 %, 2.1 ng/ml; 5–9.9 %, 2.7 ng/ml; 10–14.9 %, 3.3 ng/ml; ≥15 %, 7.7 ng/ml), and only those that lost more than 15% weight significantly increased 25OHD levels greater than control participants.[38] Changes in 25OHD levels were also associated with reductions in BMI and fat mass.[38]

Rock et al.[39] found a similar pattern with weight-change categories after a 2-year weight-loss intervention. Again, while they did not report an overall change in 25OHD levels for the entire study, they did find changes in 25OHD levels were mildly inversely correlated with changes in weight, and there was a significant linear trend between the change in 25OHD levels and weight change categories, such that those with greater weight loss had greater increases in 25OHD levels. During the study vitamin D supplement use increased from 20 % to 50 %; however, vitamin D use did not differ across the weight change categories, suggesting it was not supplement use that lead to greater increases in 25OHD in the weight-loss groups.

As mentioned above, some studies have also investigated the relationship between the changes in 25OHD levels and measures of body composition. The strength of these relationships ranges from 0.16 to 0.67, suggesting weak to strong relationships. Other studies, although not weight-loss studies, also found weak relationships between changes in fat mass and 25OHD levels.[12,17]

It appears that most studies either observed an increase in 25OHD levels, a pattern where there were greater increases in those that lost more weight or a relationship between the degree of weight loss and increases in 25OHD levels. It may be possible that a threshold of weight loss is needed to see an increase in 25OHD levels. Many of these studies were not primarily designed to measure the effect of weight loss on 25OHD levels so did not take season or prior use or changes in vitamin D supplementation into consideration in the study design, which may have greatly influenced some of the findings.

Do Baseline 25-Hydroxyvitamin D Levels Predict Subsequent Weight Loss?

It has been suggested that participants with better vitamin D status at the start of a weight-loss program may be more likely to experience successful weight loss. A study in 60 women found that those with baseline 25OHD levels 20 ng/ml or more lost more fat after 2 weeks of energy restriction compared with those with 25OHD levels less than 20 ng/ml (average 25OHD levels 31.9±15.5 versus 15.0±3.2 ng/ml; average fat loss –1.7±1.8 versus –0.5±0.8 kg, respectively).[24] When split into groups 30 ng/ml or greater and 10 ng/ml or less, again, even greater fat loss was seen in those with higher 25OHD levels (–2.9±2.2 versus –0.4±0.7 kg) and also greater weight loss (–1.6±0.8 versus –0.8±0.7 kg).[23] There was no difference in the reduction in energy intake between these groups, suggesting the baseline vitamin D status may be affecting the results, especially in those with sufficient levels. Although the sample size was small and the intervention was short, the resultant weight and fat loss was significantly greater in the group with higher 25OHD levels and suggests that those with better vitamin D status respond more positively to energy restriction and lose more fat and this could lead to even greater improvements seen over a longer time.

Shahar and colleagues[40] followed 322 men and women undergoing weight loss via three different diets and found that baseline 25OHD levels were not associated with weight loss after 2 years. However they did find that higher 25OHD levels assessed at 6 months in a representative sample (n=126) were associated with greater weight loss after 2 years (tertiles of 25OHD: 14.5, 21.2, and 30.2 ng/ml; weight loss: –3.1±5.7, –3.8±4.4, and –5.6±6.6 kg).[40] Interesting between-baseline and 6-months 25OHD levels decreased due to seasonal changes from summer to winter and when split into tertiles of change, those in the highest tertile which on average increased (median values, –9.2, –2.6 and 2.5 ng/ml) experienced greatest weight loss at 24 months (–2.5±4.9, –4.0±5.3, and –5.8±7.0 kg) and 6 months (statistics not reported, approximate values from graph, –3.5, –4, and –8 kg).[40] 25OHD values were not measured at the end of the study so unable to determine if they changed with weight loss over 24 months.

There were two other weight-loss studies that also showed no relationship between baseline 25OHD levels and subsequent weight loss.[25,38] Baseline 25OHD levels were not associated with changes in BMI, subcutaneous adipose tissue, and visceral adipose tissue after 16 weeks[25] and with greater weight loss, reductions in fat, or preservation of lean tissue after 12 months.[38] However in one study the weight loss was minimal at 2.5 kg (~3 %) and the other stated the range of 25OHD levels were low overall and the range of concentrations may have been inadequate to detect an effect.[38] Another study by Sneve et al.[15] again found no differences in weight changes when dividing the cohort according to baseline 25OHD levels, but this was not a weight-loss study and there were no changes in weight overall during the study.

Conclusions

To date there has been inconsistent findings when looking at the effects of vitamin D supplementation on weight loss. Some studies have suggested that vitamin D status is associated with weight loss success, with supplementation resulting in weight loss, or higher baseline 25OHD or greater increases in 25OHD levels predicting better weight loss, although this has not been shown in all studies. Studies have also shown variations in response to vitamin D supplementation, with inter-individual differences in the effectiveness of supplementation[41] and responses to vitamin D supplementation lower in obese participants compared with lean participants.[42,43] These studies have had numerous limitations, including the combined use of vitamin D and calcium supplementation, which again make it difficult to distinguish between the two components, the use of low or inadequate doses of vitamin D, and the impact of changing seasons on 25OHD levels. Many studies were not specifically designed to analyze the effect of vitamin D supplementation on weight loss or if 25OHD levels change with weight loss so did not take season or prior use of or changes in vitamin D supplementation into consideration in the study design, which may have greatly impacted some of the findings. Some studies also showed improvements in other body composition measures besides weight, which suggests the need for a range of body composition assessment. These inconsistent findings and limitations make it difficult to draw conclusions on the benefit of vitamin D and 25OHD levels for weight loss. Future well-designed studies primarily aimed at investigating the effect of vitamin D supplementation and statuses on weight loss and changes in body composition are needed. ■

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