European Journal of Clinical Nutrition (2015), 1–4

www.nature.com/ejcn

SHORT COMMUNICATION

Association of serum vitamin D with change in weight and total body fat in a German cohort of older adults

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We examined the association of baseline serum 25-hydroxyvitamin D (25(OH)D) with change in weight and total body fat in a cohort of community-dwelling older adults from Southern Germany. A total of 735 participants of the population-based KORA-Age Study (2009–2012), aged 65–90 years, were followed for 2.9 ± 0.1 years. Body fat was assessed with bioelectrical impedance analysis. Linear and multinomial logistic models, adjusted for baseline covariables, were used to examine the association of 25(OH)D with percentage weight and body fat change during follow-up. 25(OH)D levels were not associated with overall weight change or body fat loss. Higher 25(OH)D levels were associated with a lower likelihood of having gained >3% of body fat in women but not in men. As we cannot exclude residual confounding by outdoor physical activity and diet, our results are not sufficient to support a causal role of 25(OH)D in the etiology of obesity in Caucasian older adults.

European Journal of Clinical Nutrition advance online publication, 22 July 2015; doi:10.1038/ejcn.2015.89

INTRODUCTION

In older adults, obesity is associated with severe health consequences.[1] As weight loss, however, is only restrictively recommended to this age group, as it may have adverse effects such as sarcopenia,[1] there is an increased need to identify modifiable risk factors for excess body fat in older adults. Levels of serum 25-hydroxyvitamin D (25(OH)D) are known to be low in obese individuals.[2] Cross-sectional studies have confirmed the inverse association between 25(OH)D and body fat in older adults,[3] explicitly in women.[4] The underlying mechanism may be an increased uptake and storage of the fat soluble 25(OH)D in the expanded adipose tissue of obese subjects,[5] but results from basic studies indicate that 25(OH)D deficiency could also contribute to excess body fat through a variety of processes.[2,6] 25(OH)D levels are usually low in older adults;[7] an evaluation of 25(OH)D deficiency as a risk factor for obesity is thus of special interest. However, the prospective association between 25(OH)D and obesity has rarely been examined in the older population.[8] Accordingly, we analyzed whether baseline serum 25(OH)D levels were associated with change in weight and total body fat in a cohort of community-dwelling adults aged ⩾65 years.

MATERIALS AND METHODS

The KORA (Cooperative Health Research in the Region of Augsburg)-Age study is a population-based study conducted in Southern Germany. Details about KORA-Age have been reported elsewhere.[9] Briefly, 1079 participants aged ⩾65 years were examined at baseline in 2009, and 822 participants were reexamined at follow-up in 2012. All participants provided written informed consent. The KORA-Age study was approved by the ethics committee of the Bavarian Medical Association. Weight was measured in light clothing. Body fat was assessed with bioelectrical impedance analysis (BIA 2000-S device; Data Input GmbH, Frankfurt, Germany), using Kyle's equation to calculate total body fat from the bioelectrical impedance analysis parameters.[10] Total 25(OH)D and parathyroid hormone were measured at baseline with an enhanced chemiluminescence immunoassay (ECLIA System; Cobas e 411, Roche, Mannheim, Germany). Season of serum collection was categorized into three groups based on the observed 25(OH)D concentrations. Additional baseline information included the following: education years, smoking behavior, prevalent diseases (gastrointestinal disease, heart disease, stroke, kidney disease, liver disease, cancer, diabetes mellitus and hypertension), disability (using the Health Assessment Questionnaire Disability Index[11]), intake of medication (antihypertensives, beta blocker, lipid-lowering medication, antidiabetic medication and antidepressants), daily consumption of alcohol and physical activity (using the physical activity scale for the elderly[12]). More details on the study population and the assessment of the variables can be found in the Supplementary Material.

The association of 25(OH)D with continuous percentage change of weight and body fat per year of follow-up was assessed using linear regression, the association with categorized changes (participants who had lost >3% of their baseline weight or body fat during follow-up; participants with stable weight or body fat (⩽3% loss or gain); participants who had gained >3% of their baseline weight or body fat) using multinomial logistic regression. Complete case analysis was applied. We calculated four models with a stepwise adjustment. The full model was adjusted for age, sex, season of serum collection, parathyroid hormone and all baseline variables, which were significantly associated with both 25(OH)D and the respective outcome in a model adjusted for age and sex (P-value ⩽0.1). The logistic models were additionally adjusted for the follow-up time and the baseline value of the respective outcome. Further, an interaction term for 25(OH)D and

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Received 5 November 2014; revised 14 April 2015; accepted 29 April 2015

Table 1. Characteristics of the study population

	Quartiles of 25(OH)D levels (ng/ml)				
Characteristic	*Total*	*1.5–13.4*	*13.6–20.3*	*20.4–29.6*	*29.7–70*
n	735	184	185	183	183
Follow-up time (years), mean (s.d.)	2.9 (0.1)	—	—	—	—
Serum 25(OH)D (ng/ml), mean (s.d.)	22.18 (11.27)	—	—	—	—
BMI (kg/m^2), mean (s.d.)	28.46 (4.17)	29.67 (5.02)	28.81 (4.00)	28.15 (3.58)	27.21 (3.56)
Weight (kg), mean (s.d.)	77.29 (13.82)	78.61 (15.16)	77.38 (12.43)	77.63 (13.67)	75.52 (13.81)
Weight change per year (%), mean (s.d.)	−0.43 (1.68)	−0.72 (2.00)	−0.25 (1.53)	−0.40 (1.65)	−0.34 (1.47)
Weight change over follow-up, *n* (%)					
>3% weight loss	214 (29.1)	72 (39.1)	40 (21.6)	56 (30.6)	46 (25.1)
Weight stable	431 (58.6)	92 (50.0)	120 (64.9)	103 (56.3)	116 (63.4)
>3% weight gain	90 (12.2)	20 (10.9)	25 (13.5)	24 (13.1)	21 (11.5)
Body fat (%), mean (s.d.)	34.19 (6.94)	36.76 (6.91)	34.26 (6.92)	33.80 (6.78)	31.93 (6.33)
Body fat change per year (%), mean (s.d.)	−0.37 (4.24)	−0.41 (5.66)	0.26 (3.74)	−0.88 (3.64)	−0.47 (3.54)
Body fat change over follow-up, *n* (%)					
>3% fat loss	344 (46.8)	96 (52.2)	72 (38.9)	85 (46.4)	91 (49.7)
Fat stable	176 (23.9)	37 (20.1)	47 (25.4)	52 (28.4)	40 (21.9)
>3% fat gain	215 (29.3)	51 (27.7)	66 (35.7)	46 (25.1)	52 (28.4)
Age (years), mean (s.d.)	74.88 (6.26)	77.11 (6.31)	74.67 (6.13)	74.15 (6.10)	73.57 (5.97)
Sex, *n* (%)					
Male	378 (51.4)	76 (41.3)	93 (50.3)	99 (54.1)	110 (60.1)
Female	357 (48.6)	108 (58.7)	92 (49.7)	84 (45.9)	73 (39.9)
Serum parathyroid hormone (pg/ml), mean (s.d.)	33.71 (16.34)	43.01 (21.86)	32.34 (12.72)	31.45 (12.90)	28.01 (11.80)
Season of serum collection, *n* (%)					
February–April	227 (30.9)	69 (37.5)	67 (36.2)	49 (26.8)	42 (23.0)
May–July	318 (43.3)	75 (40.8)	78 (42.2)	87 (47.5)	78 (42.6)
August–November	190 (25.9)	40 (21.7)	40 (21.6)	47 (25.7)	63 (34.4)
Disability Index, mean (s.d.)	0.27 (0.45)	0.48 (0.61)	0.20 (0.30)	0.21 (0.39)	0.17 (0.38)
Heart disease, *n* (%)					
Yes	208 (28.3)	64 (34.8)	41 (22.2)	58 (31.7)	45 (24.6)
No	527 (71.7)	120 (65.2)	144 (77.8)	125 (68.3)	138 (75.4)
Stroke, *n* (%)					
Yes	49 (6.7)	19 (10.3)	11 (5.9)	12 (6.6)	7 (3.8)
No	686 (93.3)	165 (89.7)	174 (94.1)	171 (93.4)	176 (96.2)
Kidney disease, *n* (%)					
Yes	25 (3.4)	10 (5.4)	4 (2.2)	6 (3.3)	5 (2.7)
No	710 (96.6)	174 (94.6)	181 (97.8)	177 (96.7)	178 (97.3)
Diabetes, *n* (%)					
Yes	122 (16.6)	48 (26.1)	29 (15.7)	28 (15.3)	17 (9.3)
No	613 (83.4)	136 (73.9)	156 (84.3)	155 (84.7)	166 (90.7)
Intake of antidiabetic medicine, *n* (%)					
Yes	97 (13.2)	37 (20.1)	25 (13.5)	19 (10.4)	16 (8.7)
No	638 (86.8)	147 (79.9)	160 (86.5)	164 (89.6)	167 (91.3)
Physical activity, mean (s.d.)	123.6 (54.90)	96.6 (45.50)	132.1 (57.06)	135.4 (55.67)	130.5 (51.82)
Walking outdoors, *n* (%)					
Never	102 (13.9)	35 (19.0)	23 (12.4)	23 (12.6)	21 (11.5)
1–2 days per week	117 (15.9)	37 (20.1)	31 (16.8)	26 (14.2)	23 (12.6)
3–4 days per week	180 (24.5)	48 (26.1)	34 (18.4)	45 (24.6)	53 (29.0)
5–7 days per week	336 (45.7)	64 (34.8)	97 (52.4)	89 (48.6)	86 (47.0)
Alcohol consumption, *n* (%)					
No	246 (33.5)	80 (43.5)	67 (36.2)	49 (26.8)	50 (27.3)
Moderate	386 (52.5)	92 (50.0)	95 (51.4)	101 (55.2)	98 (53.6)
High	103 (14.0)	12 (6.5)	23 (12.4)	33 (18.0)	35 (19.1)
Smoking, *n* (%)					
Current	33 (4.5)	6 (3.3)	9 (4.9)	9 (4.9)	9 (4.9)
Former	268 (36.5)	60 (32.6)	47 (25.4)	74 (40.4)	87 (47.5)
Never	434 (59.0)	118 (64.1)	129 (69.7)	100 (54.6)	87 (47.5)
Per capita income (€/month), mean (s.d.)	1132 (558.10)	1067 (528.13)	1147 (632.21)	1141 (512.19)	1173 (550.43)
Years of education, *n* (%)					
8 years and less	140 (19.0)	51 (27.7)	33 (17.8)	29 (15.8)	27 (14.8)
9–11 years	393 (53.5)	90 (48.9)	97 (52.4)	108 (59.0)	98 (53.6)
12 years and more	202 (27.5)	43 (23.4)	55 (29.7)	46 (25.1)	58 (31.7)

Abbreviations: 25(OH)D, 25-hydroxyvitamin D; BMI, body mass index. *n* for body fat and body fat change: 683.

sex was included. All statistical analyses were carried out using SAS (Version 9.2, SAS Institute Inc., Cary, NC, USA). The code can be requested from the corresponding author.

RESULTS

As a proof of concept, the cross-sectional relationship of 25(OH)D with body mass index, weight and body fat at baseline was

Table 2. Multinomial logistic regression: association between baseline 25(OH)D and category of weight and body fat change

	% Δ weight over follow-up period (n = 735)		*% Δ body fat over follow-up period (n = 683)*	
	> 3% loss vs stable	*> 3% gain vs stable*	*> 3% loss vs stable*	*> 3% gain vs stable*
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**
25(OH)D (Model 1)	0.87 (0.73, 1.03)	0.94 (0.75, 1.12)	1.04 (0.86, 1.25)	0.96 (0.78, 1.17)
25(OH)D (Model 2)	0.90 (0.76, 1.08)	0.89 (0.70, 1.14)	1.01 (0.83, 1.24)	0.89 (0.72, 1.10)
25(OH)D (Model 3)	0.97 (0.80, 1.17)	0.93 (0.71, 1.20)	1.07 (0.87, 1.32)	0.87 (0.70, 1.09)
25(OH)D (Model 4)	0.99 (0.82, 1.21)	0.97 (0.75, 1.26)	1.10 (0.89, 1.37)	0.88 (0.69, 1.11)
25(OH)D (Model 3, men)	0.94 (0.73, 1.20)	0.93 (0.65, 1.31)	1.22 (0.90, 1.64)	1.04 (0.76, 1.42)
25(OH)D (Model 3, women)	1.01 (0.77, 1.33)	0.93 (0.65, 1.33)	0.97 (0.73, 1.28)	0.72 (0.52, 1.00)

Abbreviations: 25(OH)D, 25-hydroxyvitamin D; CI, confidence interval; OR, odds ratio. Odds ratios represent the odds of being in the loss/gain rather than in the stable group of the respective outcome for every 1 s.d. higher baseline 25(OH)D level. Significant results are printed in bold. Model 1: univariate model. Model 2: adjusted for age, sex and season of serum collection. Model 3: (i) Δ weight—additionally adjusted for disability, physical activity, smoking status, diabetes, diabetes medication, stroke, kidney disease, follow-up time and baseline weight. (ii) Δ body fat—additionally adjusted for disability, years of education, follow-up time and baseline body fat. Model 4: additionally adjusted for parathyroid hormone.

examined first. We found an inverse association, which was stronger in women. Details can be found in the Supplementary Material.

The study characteristics are shown in Table 1. In the linear models, 25(OH)D levels were not associated with percentage change in weight per year of follow-up. A weak, insignificant association was found between higher 25(OH)D levels and a reduced percentage change in body fat, which tended to be slightly stronger in women (data shown in Supplementary Table S3).

The results of the multinomial logistic models are shown in Table 2. The odds ratios represent the odds of being in the loss/gain rather than in the stable group per 1 s.d. higher 25(OH)D level. We found no association between 25(OH)D levels and category of weight change, body fat loss or body fat gain in men. In women, higher 25(OH)D levels were associated with a lower likelihood of having gained >3% of body fat (Model 3: odds ratio = 0.72 (95% confidence interval: 0.52, 1.00)). Additional adjustment for parathyroid hormone only slightly altered the association between 25(OH)D and the outcomes.

DISCUSSION

In this population-based sample of community-dwelling adults aged ⩾65 years, baseline serum 25(OH)D levels were not significantly associated with overall weight change or body fat loss over 2.9 years. Higher 25(OH)D levels were associated with a lower likelihood for body fat gain in women but not in men. Our results are in line with the only prospective study in this age group, which found no significant association between 25(OH)D and weight change over 4.5 years in women but observed that women with sufficient 25(OH)D levels showed a significant lower weight gain compared with women with levels <30 ng/ml.[8] Although these results consistently suggest that higher 25(OH)D levels may be associated with less body fat accumulation in older women, results from a meta-analysis of 12 clinical trials (some including older adults) indicate that vitamin D supplementation without caloric restriction does not significantly influence fat mass.[13]

Our study is limited by the short follow-up time, the medium sample size, a missing assessment of weight history and the small total change in weight and body fat. Bioelectrical impedance analysis was found to be valid to track changes in fat mass in older adults, but it might not accurately estimate changes of <5 kg.[14] As a consequence, we might have underestimated the true association between 25(OH)D and body fat. Even so, a reduced body fat change of 0.02% per 1 ng/ml higher baseline 25(OH)D level, as observed in this analysis, is not clinically relevant. Further, resulting from an insufficient assessment of outdoor physical activity and diet, the observed associations could be due to residual confounding by a healthy lifestyle.

In view of these limitations and conflicting evidence from clinical trials, our results are not sufficient to support a causal role of 25(OH)D in the etiology of obesity in Caucasian older adults. More research on the metabolic perturbations during both obesity and 25(OH)D deficiency is needed to further examine the 25(OH)D–obesity relationship.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ACKNOWLEDGEMENTS

This work has been supported by the "Kompetenznetz Adipositas (Competence Network Obesity)" funded by the German Federal Ministry of Education and Research (FKZ: 01GI1121B). The KORA (Cooperative Health Research in the Region of Augsburg) research platform, funded by the German Federal Ministry of Education, Science, Research and Technology and the State of Bavaria, was initiated and financed by the Helmholtz Zentrum München (German Research Center for Environmental Health, Neuherberg). As part of the 'Health in old age' program, the KORA-Age Study was financed by the German Federal Ministry of Education and Research (BMBF FKZ 01ET0713 and 01ET1003A).

REFERENCES

1 Mathus-Vliegen EM. Prevalence, pathophysiology, health consequences and treatment options of obesity in the elderly: a guideline. *Obes Facts* 2012; **5**: 460–483.
2 Earthman CP, Beckman LM, Masodkar K, Sibley SD. The link between obesity and low circulating 25-hydroxyvitamin D concentrations: considerations and implications. *Int J Obes (Lond)* 2012; **36**: 387–396.
3 Snijder MB, van Dam RM, Visser M, Deeg DJ, Dekker JM, Bouter LM *et al.* Adiposity in relation to vitamin D status and parathyroid hormone levels: a population-based study in older men and women. *J Clin Endocrinol Metab* 2005; **90**: 4119–4123.
4 Jungert A, Roth HJ, Neuhauser-Berthold M. Serum 25-hydroxyvitamin D3 and body composition in an elderly cohort from Germany: a cross-sectional study. *Nutr Metab (Lond)* 2012; **9**: 42.
5 Wortsman J, Matsuoka LY, Chen TC, Lu Z, Holick MF. Decreased bioavailability of vitamin D in obesity. *Am J Clin Nutr* 2000; **72**: 690–693.
6 Song Q, Sergeev IN. Calcium and vitamin D in obesity. *Nutr Res Rev* 2012; **25**: 130–141.
7 Holick MF. Vitamin D deficiency. *N Engl J Med* 2007; **357**: 266–281.
8 LeBlanc ES, Rizzo JH, Pedula KL, Ensrud KE, Cauley J, Hochberg M *et al.* Associations between 25-hydroxyvitamin D and weight gain in elderly women. *J Womens Health (Larchmt)* 2012; **21**: 1066–1073.
9 Peters A, Doring A, Ladwig KH, Meisinger C, Linkohr B, Autenrieth C *et al.* [Multimorbidity and successful aging: the population-based KORA-Age study]. *Z Gerontol Geriatr* 2011; **44**: 41–54.

10 Kyle UG, Genton L, Karsegard L, Slosman DO, Pichard C. Single prediction equation for bioelectrical impedance analysis in adults aged 20–94 years. *Nutrition* 2001; **17**: 248–253.
11 Fries JF, Spitz PW, Young DY. The dimensions of health outcomes: the health assessment questionnaire, disability and pain scales. *J Rheumatol* 1982; **9**: 789–793.
12 Washburn RA, Smith KW, Jette AM, Janney CA. The Physical Activity Scale for the Elderly (PASE): development and evaluation. *J Clin Epidemiol* 1993; **46**: 153–162.
13 Pathak K, Soares MJ, Calton EK, Zhao Y, Hallett J. Vitamin D supplementation and body weight status: a systematic review and meta-analysis of randomized controlled trials. *Obes Rev* 2014; **15**: 528–537.
14 Moon JR, Stout JR, Smith-Ryan AE, Kendall KL, Fukuda DH, Cramer JT *et al*. Tracking fat-free mass changes in elderly men and women using single-frequency bioimpedance and dual-energy X-ray absorptiometry: a four-compartment model comparison. *Eur J Clin Nutr* 2013; **67**: S40–S46.

Supplementary Information accompanies this paper on European Journal of Clinical Nutrition website (http://www.nature.com/ejcn)