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Objectively measured physical activity and vitamin D status in older people from Germany

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ABSTRACT

Background To analyse the seasonal relationship of objectively measured physical activity with vitamin D status in older persons from Southern Germany (latitude: 48.4°N).

Methods Physical activity was assessed in 1193 community-dwelling individuals aged ≥65 years (58% men) over 1 week using a thigh-worn accelerometer. Furthermore, the 25-hydroxyvitamin D (25(OH)D) level was measured. Least-square means of 25(OH)D serum levels were calculated for quartiles of average daily walking duration stratified by season and adjusted for gender, age and body mass index. Participants with prescribed vitamin D supplements were excluded.

Results Statistically significant linear associations between quartiles of walking duration with 25(OH)D serum levels were observed in all seasons but not in summer. Differences in 25(OH)D serum levels between the first and the last quartile were 3.42 ng/mL ($p=0.002$) in winter, 2.80 ng/mL ($p=0.009$) in spring, and 3.60 ng/mL ($p<0.001$) in the fall. The proportion of vitamin D insufficiency (<20 ng/mL) even in the highest quartile of walking duration was 45.3% in winter, 73.7% in spring, 17.4% in summer and 16.5% in the fall.

Conclusions Although a positive dose–response relationship was seen between walking duration and the 25(OH)D serum level for most seasons, vitamin D insufficiency was still very prevalent even in high-active persons during all seasons.

INTRODUCTION

Several health outcomes such as bone health, risk of falls and fracture, cardiovascular morbidity, cancer and neurodegenerative diseases are inversely associated with vitamin D serum levels.[1 2] According to a review by Holick[1] and a summary by the Endocrine Society[3] of several studies from the USA and Europe, between 40% and 100% of community dwelling older participants are considered to have vitamin D deficiency.

Sunlight exposure of unprotected skin is considered the main source of vitamin D in Europe.[4] There are currently no official recommendations for the duration and frequency of unprotected skin exposure because the time varies according to a number of environmental, physical and personal factors. However, a relatively short exposure of 5–30 min to the midsummer sun seems sufficient. The effective ultraviolet solar radiation varies throughout the year, depending on the latitude of residence.[5] Measurements of population vitamin D levels correspond highly to these variations.[6–8]

Besides the geographic location, the amounts of physical (PA) and outdoor activity, in particular as a proxy measure of sunlight exposure, seem to be important modifiable determinants of vitamin D levels. However, to date, only a few studies have investigated the association of PA with vitamin D serum levels; their results were quite inconsistent and only self-reported activity was used,[9–14] which is known to be a suboptimal exposure measure prone to bias, especially in older adults.[15]

Therefore, the aim of this study was to analyse the seasonal association of objectively measured PA (daily walking duration) with serum 25-hydroxyvitamin D (25(OH)D), the most appropriate measure of defining vitamin D status, in a population-based cohort of older persons in Southern Germany.

METHODS

The Activity and Function in the Elderly in Ulm (ActiFE Ulm) study is a population-based cohort study in participants aged ≥65 years located in Southern Germany (latitude: 48.4°N).[16] Between March 2009 and April 2010, 1506 community-dwelling individuals agreed to participate and underwent a baseline assessment.

Blood was drawn under standardised conditions during the PA measurement and analysed in a blinded fashion. The 25(OH)D serum level (ng/mL) was measured by an ElectroChemiLumineszenz ImmunoAssay (ECLIA) on a Roche E 2010 (interassay CV 4.96–5.43%). This method was standardised against liquid chromatography and compared to the National Institute of Standards and Technology (NIST) standard.[17]

PA was recorded using a validated thigh-worn uniaxial accelerometer (activPAL; PAL Technologies, Glasgow, Scotland), and classified into three categories: (1) lying or sitting, (2) standing and (3) walking.[18 19] Participants were asked to wear the device over 24 h for seven consecutive days. Only days with complete 24 h measurements were considered. Since a previous analysis showed that walking patterns on Sundays were considerably different from those on other days of the week, the average daily walking duration within 1 week was calculated only for individuals with at least one measurement on a weekday and one on a Sunday, respectively. Overall, five or more complete days were available from more than 95% of the participants. We also asked for the exact times of leaving and returning home by a diary over 1 week while wearing the accelerometer.

Generalised linear models were used to estimate least-square means of 25(OH)D serum levels for each quartile of average daily walking duration within each season: winter (December–February), spring (March–May), summer (June–August) and fall (September–November). All estimates were adjusted for gender, age and body mass index (BMI) and additionally for comorbidities (myocardial infarction, heart failure, chronic kidney disease, diabetes, neurological diseases, cancer and arthritis). Participants with prescribed vitamin D supplements were excluded (n=54). Additionally, the proportions of vitamin D deficiency (<20 ng/mL, <50 nmol/L), insufficiency (20–<30 ng/mL, 50–<75 nmol/L) and sufficiency (≥30 ng/mL, ≥75 nmol/L) were calculated for each season according to the guideline of the Endocrine Society.[3] All analyses were performed using SAS V.9.2.

RESULTS

The study population consisted of 1193 participants (58% men, mean age=75.5 (SD=6.50) years) with complete measurements on average daily walking duration, 25(OH)D serum level, and covariates (table 1). Average daily walking duration was 104.7 min (SD=40.3 min) and average 25(OH)D serum level was 20.3 ng/mL (SD=7.48 ng/mL). In total, 24.1% of participants were obese, while 9.1% were current smokers.

Figure 1A shows the associations of season and quartiles of average daily walking duration with average serum levels of 25(OH)D after adjustment for gender, age and BMI. Additional adjustment for comorbidities did not change estimates considerably. Values of 25(OH)D varied by season, with the lowest measurements in spring and highest measurements in summer. Differences in 25(OH)D serum levels between the first and the last quartile were 3.42 ng/mL in winter, 2.80 ng/mL in spring and 3.60 ng/mL in the fall. A statistically significant dose–response relationship was observed in winter (p=0.001), spring (p=0.013) and fall (p=0.001). In summer, 25(OH)D serum levels were in general the highest compared to other seasons, but walking duration did not affect the association (p=0.56).

Participants in the highest quartile of walking duration had in general the lowest proportions of vitamin D deficiency (level<20 ng/mL; figure 1B). The proportion of vitamin D deficiency according to increasing quartiles (I–IV) of walking duration were 76.3%, 77%, 60.5% and 45.3% in winter, 86.8%, 76%, 73.3% and 73.7% in spring, 37.7%, 37.7%, 17.4% and 17.4% in summer, and 54.4%, 30.8%, 28.2% and 16.5% in the fall, respectively. In general, only a few participants reached vitamin D values considered 'sufficient'.

DISCUSSION

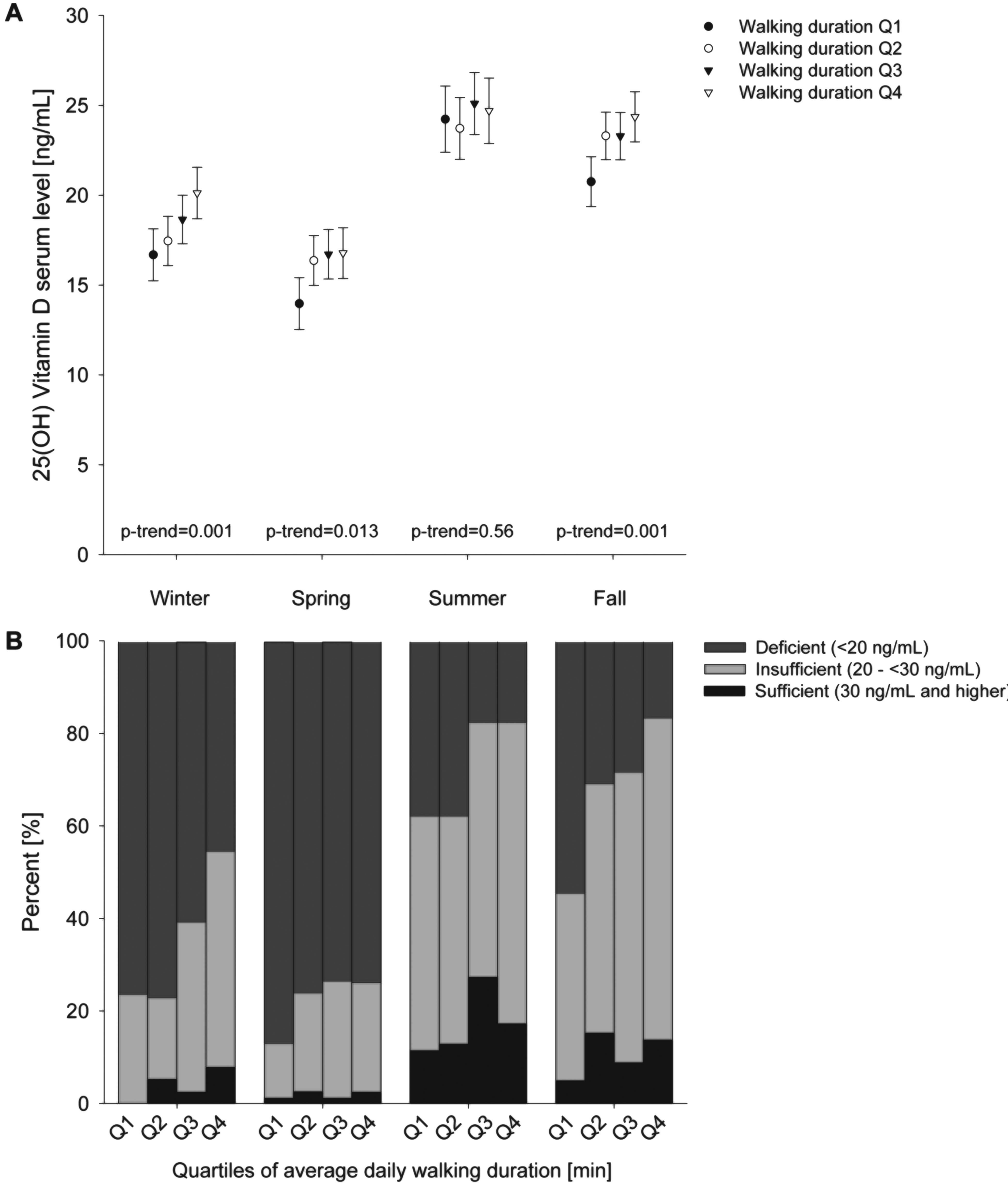
The results of this cross-sectional study suggest a positive dose–response relationship between objectively measured average daily walking duration and 25(OH)D serum levels in winter, spring and fall. It most likely reflects exposure of skin to sunlight related to outdoor activity and may open simple means for improvement of 25(OH)D serum levels in these specific seasons. During summertime, 25(OH)D serum levels were relatively high compared to the other seasons but no association with walking duration was seen. Vitamin D insufficiency was still highly prevalent during all seasons also in the group of highly active people, indicating the need of a supplementation. PA, in addition to outdoor exposure, may also be a proxy measure of better general health. This may explain the patterns in winter.

Some beneficial effects of PA on health may be partly explained due to the higher vitamin D levels as many vitamin D associated positive health effects are described in the literature.[1] Obesity is a possible modifier, since low PA may lead to a higher BMI, which might result in the lower vitamin D observed in obese persons. However, our results were controlled for body mass index. Low PA may also lead to lower outdoor activity and thereby to a lower sun exposure time. Vitamin D levels should follow the exposure to sunlight with a lag time of 6–8 weeks.[6] Surprisingly, this dose–response relationship was not seen in

Table 1 Characteristics of the study population (n=1193)

		Quartiles of walking duration (min)			
Characteristic	**Total**	**Q1**	**Q2**	**Q3**	**Q4**
Men, n (%)	692 (58.0)	173 (57.7)	168 (56.8)	171 (57.4)	180 (60.2)
Age (years), mean (SD)	75.5 (6.50)	78.8 (6.69)	75.9 (6.24)	74.7 (6.00)	72.5 (5.34)
Duration of school education (years), median (Q1-Q3)	8 (8–10)	8 (8–10)	8 (8–11)	8 (8–10)	8 (8–10)
Mild cognitive impairment (Mini Mental State Examination <25), n (%)	59 (5.3)	21 (7.6)	12 (4.4)	11 (4.0)	15 (5.3)
Body mass index (kg/m²), mean (SD)	27.6 (4.14)	29.2 (4.95)	27.8 (3.97)	27.3 (3.72)	26.3 (3.21)
≥30 kg/m², n (%)	287 (24.1)	115 (38.3)	80 (27.0)	56 (18.8)	36 (12.0)
Current smoker, n (%)	108 (9.1)	33 (11.0)	30 (10.1)	20 (6.7)	25 (8.4)
Self-reported history of comorbidity, n (%)					
Hypertension	641 (53.7)	195 (65.0)	159 (53.7)	163 (54.7)	124 (41.5)
Myocardial infarct	105 (8.8)	43 (14.3)	28 (9.5)	18 (6.0)	16 (5.4)
Heart failure	179 (15.0)	68 (22.7)	50 (16.9)	32 (10.7)	29 (9.7)
Cancer	218 (18.3)	66 (22.0)	55 (18.6)	62 (20.8)	35 (11.7)
Chronic kidney disease	39 (3.3)	16 (5.3)	14 (4.7)	4 (1.3)	5 (1.7)
Diabetes	170 (14.3)	70 (23.3)	46 (15.5)	34 (11.4)	20 (6.7)
Neurological disease	65 (5.5)	22 (7.3)	20 (6.8)	14 (4.7)	9 (3.0)
Arthritis	528 (44.3)	136 (45.3)	135 (45.6)	128 (43.0)	129 (43.1)
Average daily walking duration (min), mean (SD)	104.7 (40.3)	56.3 (16.7)	90.5 (8.2)	115.2 (8.4)	156.7 (26.1)
Average daily time spent out of home (min), mean (SD)*	232.5 (119.5)	154.0 (93.5)	216.8 (112.6)	257.6 (110.1)	297.8 (111.4)
25(OH) Vitamin D serum concentration (ng/mL), mean (SD)	20.3 (7.48)	17.9 (7.91)	20.0 (7.30)	21.0 (6.96)	22.2 (7.07)

*Data available for n=1149 (96.3%).



n	301	302	276	314
Q1	0 - <71.9	0 - 76.7	0 - 78.4	0 - 80.5
Q2	71.9 - <98.2	76.7 - 104.9	78.4 - 105.6	80.5 - 103.7
Q3	98.2 - 123.7	104.9 - 126.1	105.6 - 136.4	103.7 - 129.2
Q4	≥123.7	≥126.1	≥136.4	≥129.2

Figure 1 Association of season and quartiles of average daily walking duration with serum levels of 25-hydroxyvitamin D after adjustment for gender, age and body mass index as well as vitamin D status in community-dwelling individuals aged ≥65 years living in Germany assessed between March 2009 and April 2010. Participants with prescribed vitamin D supplements were excluded

summer where the effective ultraviolet solar radiation and the daylight time reach its maximum of the year, but was seen in winter where there is not enough UVB radiation for vitamin D production in Germany. During summer, relevant sunlight exposure might also be related to other outdoor activities such as sitting or lying. During winter, PA might partly reflect better general health.

Our findings are in line with previous publications, which mostly showed an association of self-reported PA or outdoor activity with 25(OH)D serum levels.[9–13] Van den Heuvel *et al*[14] found an association only between energy expenditure and vitamin D for women but not for men and not for total time spent in specific activities. In these studies, measures of PA were derived from questionnaires and varied considerably between, for example, outdoor activity and recreational PA. Scragg and Camargo[10] also analysed the effect of vigorous PA and vitamin D by season in the USA and found a positive dose–response relationship in every time interval.

Notably, in some studies in which PA was considered as a surrogate marker for sunlight exposure, the relationship persisted for PA after adjusting for self-reported sun exposure.[12] Whether some aspects of PA other than increasing sun exposure are playing a role is unclear yet and should be explored further. We were not able to control well for outdoor activity. However, self-reported information on time spent out of home from 96% of the participants suggests that, even in summer, time spent out of home (and thus partly outdoor) was at least tentatively related to higher vitamin D levels (Spearman correlation coefficient: 0.32 ($p<0.001$)).

When considering the overall vitamin D status of the population, it has to be stated that during all seasons vitamin D insufficiency was very common. Notably, even during summer, when 25(OH)D serum levels reached the highest levels during seasonal variation, a large proportion of especially older persons still has to be considered to have suboptimal levels according to the recommendations of the Endocrine Society.[3]

Several limitations should be considered: we could not differentiate between indoor and outdoor activity. Therefore, average daily walking duration does not directly represent total sunlight exposure. Direct assessment of outdoor activity using polysulfone badges or electronic dosimeters might increase the magnitude of the observed associations. Furthermore, vitamin D serum level and walking duration over 1 week was measured only once for each participant. Assessments at several points throughout the year might have improved the results. Moreover, we were not able to control for any changes of the participant's latitude (eg, due to holidays), which might have affected the vitamin D serum levels. 32.6% of the blood samples were not measured in fasting state. However, excluding all non-fasted blood samples in a sensitivity analysis did not change the results considerably. Finally, we were not able to adjust for dietary nutrient intake, clothing during outdoor activity, skin type or use of sunblocks.

The major strength of this study is the objectively measured PA in a large population-based sample of community-dwelling older people. Furthermore, 25(OH)D measurements over 1 year were available. All estimates were adjusted for gender, age and BMI and further control for relevant comorbidities did not change the results. In addition, participants with prescribed vitamin D supplements were excluded.[20]

In conclusion, our results suggest that walking duration, which most likely reflects exposure to sunlight related to outdoor activity as well as a better general health status, is associated with 25(OH)D serum levels in winter, spring and fall in this reasonably healthy older population. Nevertheless, even in persons in the top quartile of walking duration, vitamin D insufficiency is still prevalent during all seasons of the year, indicating that supplementation may be required.

What is already known on this subject?

- Physical activity as a proxy measure for good health in general as well as an indirect measure of sunlight exposure might be an important determinant of vitamin D levels.
- Only a few studies have investigated the association of physical activity with vitamin D serum levels by season.

What this study adds?

- A positive dose–response relationship between walking duration and 25-hydroxyvitamin D serum level was found for most seasons in this older population, but not for summer.
- Vitamin D insufficiency was very prevalent even in physically high-active persons during all seasons.

Collaborators The ActiFE Ulm study group consists of following members: H Geiger, Department of Dermatology and Allergology; A Lukas, Agaplesion Bethesda Clinic, Ulm; M Riepe, Division of Gerontopsychiatry, Department of Psychiatry and Psychotherapy II; L Rudolph, Max-Planck Group for Stem Cell Research; K Scharffetter-Kochanek, Department of Dermatology and Allergology; C Schumann, Department of Internal Medicine II—Pneumology; JM Steinacker, Department of Internal Medicine II—Sports and Rehabilitation Medicine; A Ludolph, C von Arnim, Department of Neurology; F Herbolsheimer, G Weinmayr, Institute of Epidemiology and Medical Biometry. All Institutes are located at Ulm University.

Contributors KR, MD, RP and TN were involved in study design and organising funding. JK and DR took part in data analysis and drafting of the manuscript. JK, KR, MD, GN, TN, RP, BOB, WK and DR participated in data interpretation. KR, MD, GN, TN, RP, BOB and WK were involved in revision of the manuscript. JK, KR, MD, GN, TN, RP, BB, WK and DR approved the final version of the manuscript. JK takes responsibility for the integrity of the data analysis.

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Competing interests None.

Ethics approval Ethical Committee Ulm University.

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