



Functional capacity, renal function and vitamin D in community-dwelling oldest old

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Abstract

Purpose The aim of this study was to evaluate the association between the decline in estimated glomerular filtration rate (eGFR) and serum 25(OH)D with the physical and mental functional capacity of elderly individuals aged 80 years or older.

Methods We evaluated the functional capacity in its multidomain aspects: Geriatric Depression Scale (GDS), Instrumental Activities of Daily Living (IADL), Mental State Mini-Exam (MMSE), Verbal Fluency Test (VF), handgrip strength and time to sit and rise from a chair five times, combined creatinine and cystatin C-based eGFR and 25(OH)D levels in 205 independent asymptomatic and community-dwelling elderly subjects in a cross-sectional study.

Results Every 1 year of life, there was reduction of about 10% chance of adequate performance in functional capacity. Each 1 ml/min/m² in eGFR was associated with 2% better chance of adequate performance in the IADL. We found no association between eGFR and cognition. Serum 25(OH)D between 15.00 and 22.29 ng/ml increased the chance of better performance in VF, IADL, handgrip strength and sit and rise from the chair compared to the lower level of serum vitamin D.

Conclusions Decreased renal function associated with age compromises the ability to perform activities for independent life in the community, but we did not observe influence in specific domains of cognition and physical performance. Low serum level of 25(OH)D appears to be a marker of greater risk of functional decline than eGFR measurement in independent oldest old dwelling in the community.

Keywords Renal function · Vitamin D · Cognition · Physical performance · Oldest old

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Introduction

The prevalence of vitamin D deficiency increases with age and the low serum 25(OH) vitamin D levels have been associated with declining muscle contraction, physical function, and cognitive function [1–5]. 25(OH)D is the main form of circulating vitamin D. It has been studied as a hormone with actions at multiple sites and as modulator of the immune response [6, 7]. In the muscles, vitamin D has the effect of regulating calcium uptake and also a direct stimulation effect of protein synthesis and muscle cell growth [8]. Although the enzyme that activates 25(OH)D in its 1,25 form (diOH) D is present in various tissues [9], the kidney is its major hydroxylation site. Thus, decline in renal function may lead to disorders in vitamin D metabolism.

There is great variability in the rate of renal aging from one person to another. A 10-year increase in age after age 40 is related to a 2.3-fold greater chance of developing a GFR of less than 60 ml/min/1.73 m² [10]. The expected rate of normal decline of GFR with aging ranges from 6.3 to 7.5 ml/min/1.73 m² per decade of age [11, 12], but most people have comorbidities and cardiovascular risk factors beyond normal aging that can accelerate this decline. Decreased glomerular filtration rate (GFR) is associated with mortality and physical and cognitive impairment [13–19].

Functional capacity is the ability of the elderly to take care of their own lives and to live with independence and autonomy in the community. Because functional capacity encompasses complex tasks that require multiple integrated domains, such as muscle strength, balance, fitness, attention, memory, praxia, and mood, both renal function and low levels of 25(OH)D may impair performance of Instrumental Activities of Daily Life (IADL) and lead the elderly to dependence.

Objective

The aim of this study was to evaluate the association between the decline in eGFR and serum 25(OH)D with the physical and mental functional capacity of elderly individuals aged 80 years or older.

Methods

Study participants

This is a cross-sectional study of data from 205 independent for basic activities of daily living (ADL) [20], free-living oldest old subjects, recruited from the “Longevity Project”

between 2010 and 2012. The “Longevity Project” is a cohort of community-dwelling elderly aged 80 years or older of the southern region of city of São Paulo, Brazil, coordinated by the Geriatrics Division of the Federal University of São Paulo. The participants were recruited by advertisement at local neighborhood newspapers, radio media and referral from other departments of the University. They could walk without human support, all chronic conditions were under control and they did not have cognitive impairment complaints. 360 elderly subjects were initially evaluated; of which, 155 were not included because they were unable or unwilling to give consent to answer the tests, known cognitive impairment, end-life disease, acute and not controlled chronic diseases. All participants gave their written informed consent and the Research Ethics Committee of the Federal University of São Paulo approved the study protocol number 1532/09.

Geriatric assessment

Trained physicians interviewed all participants on sociodemographic, clinical, and medication inventory. We also reviewed the medical records of individuals when they were available. Weight and height were obtained by means of scales calibrated in kilograms and a stadiometer in centimeters 25 and used to calculate body mass index (BMI). The self-reported functional capacity was assessed by the Instrumental Activities of Daily Life (IADL) [21], which included telephone use, shopping, food preparation, transportation use, cleaning, and medication use, with a score of 7–21. Good performance (21 points) in IADL means independence. Depressive symptoms were investigated using the Geriatric Depression Scale (GDS) of 15 items [22]. The Mini-Mental State Examination (MMSE) [23, 24] and the Verbal Fluency Test (VF) by Category [25, 26] assessed cognitive function. The MMSE is a global cognition test that is punctuated by 30 points. VF is used as a measure of language, executive functions and semantic memory. We asked the subjects to produce as many animals’ names as possible in a period of 1 min and we counted the number of animals named. We define the adequacy of performance as dependent on schooling, according to a study by Brucki et al. [24, 25]. The timed ability to rise from a chair was used to test the function of the lower extremities. Participants were asked (and timed) to get up and sit in a chair five times as fast as possible and we used the results of Guralnik [26] to define adequate performance. To test the functionality of the upper extremities, we use the handgrip strength of the dominant hand. The subjects rested in a sitting position on the armless chair, and then were asked to hold a Jamal dynamometer [27] as tightly as possible. We took the best of the three trials of grip strength. The value considered

appropriate according to sex was > 16 kg for women and > 26 kg for men [28].

Laboratory evaluation

Blood samples were collected after a 12-h fast in the fall. Serum concentration of 25(OH)D was determined by chemiluminescence using the LIAISON® 25OHvitaminD-310600 (DiaSorin Inc., USA) assay. Serum creatinine was measured using a modified Jaffé colorimetric kinetic method on a self-analyzer (Beckman Coulter AU 400, CA, USA), which was calibrated for isotope dilution mass spectrometry (IDMS) using a traceable standard reference material (914a) to the National Standards and Technology Institutes (NIST). The total analytical variation (CV%) of the colorimetric method was 1.4–3.0%. The variation of intra-assay coefficient (CV) for creatinine was 1.9%. Plasma cystatin C levels were determined by an automated immunostimulatory method of particles using a Beckman AU 400 analyzer (Beckman Coulter, Inc. CA, USA), reagents (codes LX002, S2361, X0973, X0974) obtained from DakoCytomation (Glostrup Denmark) and following the procedures recommended by the reagent producer. The intra-assay CV was 4.7% and the inter-assay CV was 5.2% at a level of 1.0 mg/l cystatin C. All samples were frozen at -80 °C and analyzed in of 7 days of collection. We estimated the glomerular filtration rate (eGFR) by the CKD-EPI equation creatinine-cystatin C, which incorporates age, sex, race, serum creatinine and cystatin C because it has the best accuracy and precision compared to iohexol clearance in this very older population as previously reported [29].

Statistical analysis

Data were analyzed descriptively. Absolute and relative frequencies were used for the categorical variables and summary-measures (mean and standard deviation) for numerical variables. The stocks of associations between two categorical variables were verified using the Chi square test. When differences were observed in the distribution, the standardized residual was used to identify the local differences—cells with absolute values above 1.96 indicate evidence of associations between the categories related to these cells. The comparison of means between two groups was performed using Student's *t* test for independent samples. Student's *t* test presents as one of the assumptions the normality in the data distribution, which was verified using the Kolmogorov–Smirnov test. The comparison of more than two groups was performed using the Kruskal–Wallis test due to the violation of the normality assumption in the distribution of variables. Once the mean differences in this test were detected, the identification of groups with different means was performed through multiple Dunn–Bonferroni

comparisons, maintaining an overall significance level of 5%.

The effects of 25(OH)D and renal function on the functional adaptations (GDS, MMSE, VF, IADL, Handgrip Strength and Chair Sit and Rise) were evaluated using logistic regression analyzes, adjusted by gender and age. In the logistic regression model, the exponentiated coefficients are interpreted as odds ratio. In this study, the chance consists of the quotient between the probability of adequacy (or good performance) and that of inadequacy (poor performance) of each functional characteristic tested as outcome variable. In these analyzes the interaction between 25(OH)D and eGFR was evaluated. A significance level of 5% was used for all statistical tests. Statistical analyzes were performed using the statistical software SPSS 20.0.

Results

Data from 205 elderly people, whose mean age was 85.0 years (SD = 4.0 years, 80–97 years), were analyzed. The majority of these people were women (68.8%), Caucasians (66.7%), with a low average educational level (4.8 years \pm 4.1), with an average of four chronic diseases and taking on average of six medications. The mean eGFR was 51 (\pm 14) ml/min/1.73 m² and the mean serum level of 25(OH)D was 19.8 (\pm 8.1) ng/ml. Table 1 presents the clinical and demographic characteristics to this sample according to the tertiles of eGFR and vitamin D. The elderly with the highest mean age were found in the lowest tertiles of eGFR and 25(OH)D serum. The men were in a higher proportion in the serum vitamin D group of 15–22 ng/ml. There was a higher proportion of chronic diseases among the elderly in the upper tertile of 25(OH)D serum (above 22 ng/ml). The use of vitamin D supplements occurred in 42% of the elderly, with the highest proportion of users being in the upper tertile of serum 25(OH)D compared to the lower tertile (61% vs. 27%, respectively, $p < 0.001$). The elderly in the lower tertile of serum 25 (OH) D had higher mean serum PTH levels.

Regarding performance in functional capacity, 55% of the very old presented good performance in the cognitive tests MMSE and VF. In relation to IADL, 41.5% of the subjects were classified as appropriate. In addition, 72.8% and 46.9% presented appropriate performance in the handgrip strength and in the to sit and stand up of the chair 5 times in seconds, respectively (Supplementary Material). We found that long-lived subjects with appropriate e GDS had a mean serum 25(OH)D higher than those with inappropriate GDS (20.4 \pm 8.3 vs. 17, 6 \pm 7.0 ng/ml, $p = 0.049$). In addition, those with inappropriate in IADL had a greater mean of 25(OH)D (18.3 \pm 8.3 vs. 21.8 \pm 7.4 ng/ml, respectively, $p = 0.002$) and of eGFR (54 \pm 13 vs. 48.4 \pm 13.5 ml/

Table 1 Demographic and clinical characteristics according to tertiles of eGFR and 25(OH)D levels

Characteristics	All (n=205)	eGFR (ml/min/1.73 m ²)			p	25(OH)D (ng/ml)			p
		17–45	45–56	56–91		5.8–15	15–22.3	22.3–48.0	
		n=71	n=69	n=65		n=66	n=69	n=70	
eGFR (ml/min/1.73 m ²)	51 ± 14	–	–	–	–	49 ± 15	52 ± 15	51 ± 11	0.505
25(OH) D (ng/ml)	19.8 ± 8.1	19.3 ± 8.4	20.3 ± 8.6	19.8 ± 7.3	0.773	–	–	–	–
Age (years)	85.0 ± 4.0	86.3 ± 4.4 ^A	84.9 ± 3.7	83.6 ± 3.4 ^B	0.001 ^a	86.1 ± 4.5 ^A	84.3 ± 3.6 ^B	84.6 ± 3.8 ^B	0.037 ^a
Gender					0.972				0.032 ^a
Male	64 (31.2)	22 (31.0)	21 (30.4)	21 (32.3)		14 (21.2) ^B	29 (42.0) ^A	21 (30.0)	
Female	141 (68.8)	49 (69.0)	48 (69.6)	44 (67.7)		52 (78.8)	40 (58.0)	49 (70.0)	
Race					0.203				0.971
White	136 (66.7)	52 (74.3)	45 (65.2)	39 (60.0)		44 (67.7)	46 (66.7)	46 (65.7)	
Non-Whites	68 (33.3)	18 (25.7)	24 (34.8)	26 (40.0)		21 (32.3)	23 (33.3)	24 (34.3)	
Education (years)	4.8 ± 4.1	4.6 ± 4.1	5.0 ± 4.1	4.9 ± 4.2	0.837	4.4 ± 3.7	5.3 ± 4.7	4.8 ± 3.9	0.689
Number of chronic disease	4.3 ± 1.9	4.6 ± 1.9	4.2 ± 1.9	4.1 ± 1.8	0.286	3.8 ± 1.7 ^B	4.5 ± 2.1	4.6 ± 1.7 ^A	0.041 ^a
Number of usual medications	5.7 ± 2.7	6.3 ± 3.0	5.5 ± 2.6	5.3 ± 2.3	0.085	5.1 ± 3.0	5.8 ± 2.6	6.3 ± 2.3	0.055
Vitamin D supplements	86 (42.4)	27 (38.6)	32 (47.1)	27 (41.5)	0.593	18 (27.7)	25 (36.8)	43 (61.4)	<0.001 ^a
Nutritional status (BMI, kg/m ²)					0.613				0.455
Undernutrition (<23)	40 (19.8)	14 (19.7)	12 (17.6)	14 (22.2)		15 (22.7)	11 (16.4)	14 (20.3)	
Normal weight (≥23 to <28)	88 (43.6)	28 (39.4)	35 (51.5)	25 (39.7)		24 (36.4)	36 (53.7)	28 (40.6)	
Overweight (≥28 to <30)	35 (17.3)	14 (19.7)	12 (17.6)	9 (14.3)		12 (18.2)	8 (11.9)	15 (21.7)	
Obesity (≥30)	39 (19.3)	15 (21.1)	9 (13.2)	15 (23.8)		15 (22.7)	12 (17.9)	12 (17.4)	
PTH (pg/ml)	62.5 ± 32.3	67.3 ± 35.8	61.2 ± 31.0	58.6 ± 29.1	0.367	71.7 ± 39.2 ^A	60.6 ± 28.4	55.7 ± 26.4 ^B	0.025 ^a
Creatinine (mg/dl)	0.98 ± 0.30	1.22 ± 0.35 ^A	0.94 ± 0.14 ^A	0.77 ± 0.15 ^B	<0.001 ^a	0.96 ± 0.28	1.02 ± 0.40	0.97 ± 0.19	0.704
Cystatin C (mg/L)	1.51 ± 0.38	1.89 ± 0.33 ^A	1.44 ± 0.17 ^B	1.18 ± 0.14 ^C	<0.001 ^a	1.57 ± 0.43	1.50 ± 0.40	1.48 ± 0.29	0.554

A, B and C have different means from multiple comparisons of Dunn-Bonferroni. A', B' and C' have different means from Duncan multiple comparisons

eGFR estimated glomerular filtration rate by CKD-EPI creatinine–cystatin C equation, 25(OH)vitD serum 25(OH) cholecalciferol concentration, Vit D Supplements oral cholecalciferol, PTH parathyroid hormone, BMI body mass index [30]. Values are mean ± standard deviation or n (%). p descriptive level of Chi square test or Kruskal–Wallis/ANOVA (^a)

min/1.73 m², respectively, $p=0.003$) compared to those with good performance (Supplementary Material).

According to Table 2, there were associations between 25(OH)D classified in tertiles and the variables VF ($p=0.020$), IADL ($p=0.001$) and handgrip strength ($p=0.038$). 40% of the elderly with poor performance in VF, 42.5% of those with inappropriate performance in IADL and 43.5% with inadequate handgrip strength were in the lowest serum 25(OH)D level group. On the other hand, 41.1% of those with good performance in VF and 38.1% with appropriate handgrip strength were in the intermediate group of 25 (OH) D and 43.5% of elderly with appropriate performance in IADL were in the group of higher serum level of 25(OH)D.

According to Table 3, there was a tendency of a higher proportion of elderly with inappropriate performance in IADL (40%) in the group with lower eGFR tertile. There

was no significant difference between the eGFR tertiles compared to the GDS, MMES, VF, IADL, Handgrip Strength and Chair Sit and Rise test.

In the logistic regression models, we included the significant variables in the previous analyzes: age, sex, 25(OH)D and eGFR in relation to the functional measures (Table 4). The interaction between GFR and 25(OH)D was not significantly associated with any of the functional capacity measures. Therefore, we did not include the interaction in the subsequent models. Models 1 and 2 show the variables eGFR and 25(OH)D classified as categorical or continuous. The chance of not having depressive symptoms (GDS ≤ 5) was 2.8 times higher in men than in women [OR 95% CI 2.81 (1.14–6.89), $p=0.024$]. At every 1 year of increase in age, there was a reduction of about 10% in functional capacity, according to the MMSE, IADL and Handgrip Strength tests. Serum 25(OH)D between 15.00 and 22.29 ng/ml increased

Table 2 Distribution of very older by tertiles of 25(OH)D and functional performance

	25(OH)D (ng/ml)			<i>p</i>
	< 15.00 <i>n</i> = 66	15.00–22.29 <i>n</i> = 69	22.30+ <i>n</i> = 70	
GDS, <i>N</i> (%)				0.251
Inappropriate (> 5), <i>n</i> = 43	18 (41.9)	14 (32.6)	11 (25.6)	
Appropriate (≤ 5), <i>n</i> = 162	48 (29.6)	55 (34.0)	59 (36.4)	
MMSE, <i>N</i> (%)				0.710
Poor performance, <i>n</i> = 92	32 (34.8)	31 (33.7)	29 (31.5)	
Good performance, <i>n</i> = 113	34 (30.1)	38 (33.6)	41 (36.3)	
VF, <i>N</i> (%)				0.020
Poor performance, <i>n</i> = 93	37 (39.8)	23 (24.7)	33 (35.5)	
Good performance, <i>n</i> = 112	29 (25.9)	46 (41.1)	37 (33.0)	
IADL, <i>N</i> (%)				0.001
Inappropriate (≤ 20), <i>N</i> = 120	51 (42.5)	36 (30.0)	33 (27.5)	
Appropriate (= 21), <i>N</i> = 85	15 (17.6)	33 (38.8)	37 (43.5)	
Handgrip strength, <i>N</i> (%)				0.038
Inappropriate, <i>n</i> = 55	24 (43.6)	12 (21.8)	19 (34.5)	
Appropriate, <i>n</i> = 147	40 (27.2)	56 (38.1)	51 (34.7)	
Chair sit and rise 5 times, in seconds, <i>N</i> (%)				0.052
Inappropriate (> 16.6), <i>n</i> = 103	39 (37.9)	28 (27.2)	36 (35.0)	
Appropriate (≤ 16.6), <i>n</i> = 91	22 (24.2)	38 (41.8)	31 (34.1)	

GDS Geriatric Depression Scale, MMSE Mini-Mental State Examination, VF Category Verbal Fluency Test, IADL Instrumental Activity Daily Life. *p* descriptive level of the Chi-square test

Table 3 Distribution of very older by eGFR levels and functional performance

	eGFR (ml/min/1.73 m ²)			<i>p</i>
	< 45.00 <i>n</i> = 71	45.00–55.99 <i>n</i> = 69	56.00+ <i>n</i> = 65	
GDS, <i>N</i> (%)				0.132
Inappropriate (> 5), <i>n</i> = 43	17 (39.5)	9 (20.9)	17 (39.5)	
Appropriate (≤ 5), <i>n</i> = 162	54 (33.3)	60 (37.0)	48 (29.6)	
MMSE, <i>N</i> (%)				0.147
Poor performance, <i>n</i> = 92	31 (33.7)	37 (40.2)	24 (26.1)	
Good performance, <i>n</i> = 113	40 (35.4)	32 (28.3)	41 (36.3)	
VF, <i>N</i> (%)				0.857
Poor performance, <i>n</i> = 93	32 (34.4)	33 (35.5)	28 (30.1)	
Good performance, <i>n</i> = 112	39 (34.8)	36 (32.1)	37 (33.0)	
IADL, <i>N</i> (%)				0.061
Inappropriate (≤ 20), <i>n</i> = 120	48 (40.0)	41 (34.2)	31 (25.8)	
Appropriate (= 21), <i>n</i> = 85	23 (27.1)	28 (32.9)	34 (40.0)	
Handgrip strength, <i>N</i> (%)				0.772
Inappropriate, <i>n</i> = 55	17 (30.9)	19 (34.5)	19 (34.5)	
Appropriate, <i>n</i> = 147	53 (36.1)	49 (33.3)	45 (30.6)	
Chair Sit and Rise 5 times, in seconds, <i>N</i> (%)				0.370
Inappropriate (> 16.6), <i>N</i> = 103	40 (38.8)	32 (31.1)	31 (30.1)	
Appropriate (≤ 16.6), <i>N</i> = 91	27 (29.7)	35 (38.5)	29 (31.9)	

GDS Geriatric Depression Scale, MMSE Mini-Mental State Examination, VF Category Verbal Fluency Test, IADL Instrumental Activity Daily Life. *p* descriptive level of the Chi-square test

Table 4 Results of logistic regression analyzes in relation to functional performance

Adequacy												
	GDS		MMSE		VF		IADL		Handgrip strength		Chair sit and rise	
	RC (95% CI)	<i>p</i>	RC (95% CI)	<i>p</i>	RC (95% CI)	<i>p</i>						
Model 1												
Male	2.81 (1.14–6.89)	0.024	1.39 (0.74–2.60)	0.311	0.88 (0.47–1.63)	0.677	1.80 (0.94–3.46)	0.077	0.39 (0.19–0.79)	0.009	1.35 (0.72–2.55)	0.348
Age (years)	1.00 (0.92–1.10)	0.955	0.90 (0.84–0.98)	0.009	0.96 (0.89–1.04)	0.329	0.89 (0.82–0.97)	0.008	0.87 (0.80–0.95)	0.001	0.98 (0.90–1.06)	0.540
25(OH)D (ref. = up 15)		0.310		0.784		0.048		0.009		0.050		0.110
15.00–22.29	1.29 (0.55–3.03)	0.551	0.87 (0.42–1.79)	0.700	2.46 (1.19–5.07)	0.015	2.35 (1.07–5.14)	0.033	3.01 (1.24–7.28)	0.015	2.21 (1.05–4.66)	0.036
22.30+	1.97 (0.83–4.70)	0.127	1.11 (0.55–2.25)	0.771	1.37 (0.69–2.73)	0.368	3.31 (1.53–7.16)	0.002	1.51 (0.69–3.32)	0.305	1.47 (0.71–3.02)	0.299
eGFR (ref. = 56 or more)		0.117		0.173		0.906		0.348		0.206		0.409
<45.00	1.15 (0.50–2.65)	0.741	0.99 (0.48–2.06)	0.977	1.08 (0.52–2.22)	0.841	0.57 (0.27–1.22)	0.147	2.21 (0.92–5.29)	0.075	0.81 (0.38–1.72)	0.583
45.00–55.99	2.52 (1.00–6.31)	0.049	0.56 (0.28–1.14)	0.110	0.92 (0.46–1.86)	0.819	0.73 (0.35–1.53)	0.406	1.49 (0.65–3.40)	0.344	1.31 (0.63–2.70)	0.472
Model 2												
Male	2.74 (1.13–6.60)	0.025	1.34 (0.72–2.47)	0.351	1.01 (0.55–1.84)	0.973	1.97 (1.04–3.75)	0.039	0.48 (0.24–0.94)	0.032	1.54 (0.83–2.84)	0.168
Age (years)	0.99 (0.91–1.09)	0.898	0.90 (0.84–0.97)	0.008	0.95 (0.88–1.02)	0.146	0.89 (0.82–0.97)	0.006	0.85 (0.78–0.93)	<0.001	0.96 (0.89–1.04)	0.308
25(OH)D	1.04 (1.00–1.09)	0.065	1.01 (0.98–1.05)	0.553	1.02 (0.98–1.05)	0.364	1.05 (1.01–1.09)	0.007	0.99 (0.96–1.03)	0.765	1.01 (0.97–1.05)	0.636
eGFR	0.99 (0.96–1.01)	0.391	0.99 (0.97–1.02)	0.596	0.99 (0.97–1.01)	0.504	1.02 (1.00–1.05)	0.041	0.98 (0.95–1.00)	0.071	1.00 (0.98–1.02)	0.906

GDS Geriatric Depression Scale, MMSE Mini-Mental State Examination, VF Category Verbal Fluency Test, IADL Instrumental Activity Daily Life, RC Chance ratio, 95% CI 95 confidence interval

the chance of better performance in VF [OR, 95% CI 2.46 (1.19–5.07)], IADL [OR, 95% CI 2.35 (1.07–5.14)], handgrip strength [OR, 95% CI 3.01 (1.24–7.28)] and sit and rise from the chair 5 times [OR, 95% CI 2.21 (1.05–4.66)] compared to the lower tertile group of vitamin D. This chance of independence in IADL was even higher in the upper tertile of 25(OH)D. In the middle tertile eGFR the chance of not having depressive symptoms was marginally higher than in the highest tertile [OR, 95% CI 2.52 (1.00–6.31)]. In addition, at each 1 ml/min/1.73 m² increase in eGFR, there was a 2% increase in the chance of adequate IADL [OR, 95% CI 1.02 (1.00–1.05), $p=0.041$].

Discussion

The effect of aging on health is the result of the interaction of physiological factors, diseases and environment, and functional capacity is the best way to understand the consequences of these factors on the health of an elderly person and to identify vulnerabilities. Functional capacity is the ability of the elderly to deal with problems, take care of one's life and adapt to everyday challenges. It is usually evaluated in the areas of mental health, physical performance and ability to perform tasks.

Decreased GFR has an impact on functional capacity [30]; and low levels of 25(OH)D have also been associated with poor performance in function and mobility [31]. We studied the associations of eGFR and serum vitamin D levels in the domains of mental health, physical performance, and independence in instrumental life activities in elderly people aged 80 years and older, independent of self-care, community residents with chronic diseases, 69% of the elderly with a decline in their renal function [29].

In this study, we found that 55% of these elderly people have adequate cognitive performance, 72% of them have preserved muscle strength, 47% could sit and stand from the chair without the help of their hands in a timely manner (sit-to-stand task), so they had the necessary physical functions (strength, balance and postural control) for the task, and 41% were independent in the tasks of IADLs, which are fundamental to living independently in the community.

In our study, aging per se had an impact on functional capacity: every 1 year of life, there was a reduction of about 10% chance of adequate performance in the IADL, the MMSE and the handgrip strength. However, regardless of aging, we found an association between eGFR and IADL. Each 1 ml/min/m² was associated with a 2% better chance of adequate performance in the IADL. Bowling et al. studied elderly with an average age of almost 80 years seeking associations of eGFR with geriatric syndromes, mobility problems and daily tasks [30, 32, 33]. These authors reported that elderly patients with GFR < 45 ml/min/m² had a greater

than threefold decline in ADL and IADL compared to the elderly with GFR > 60 ml/min/m² in the REGARDS cohort, and had a higher prevalence of cognitive deficit, exhaustion, falls, mobility, social participation and polypharmacy. The presence of these geriatric syndromes in the population studied by Bowling et al. indicates a compromise in multiple systems that accelerate renal decline and functional disability. It appears that we have studied a population with a more preserved overall health, and possibly this is the reason for the difference in strength of the association between eGFR and functional capacity.

We found no association between eGFR and cognitive function. Although some studies [34] showed the importance of renal disease in cognition in adults, in the elderly this relation is less clear. Perhaps, because the decline in eGFR in the elderly does not necessarily mean that there is renal disease, and therefore, the findings of cognitive impairment are not unanimous, especially in the elderly. Pottelberg et al. followed 378 elderly people, aged over 85 years, for 3 years, 13% were residents of long-term institutions and, therefore, probably more dependent than community residents. They failed to show association between eGFR and MMSE [35]. A neuropsychological battery could assess cognitive function in a broader, more specific and sensitive way than MMSE. However, these more subtle deficits may have less practical relevance in daily life, and MMSE is the most commonly used screening test in clinical practice.

The presence of 25(OH)D receptors in brain and muscle tissue supports the study of their effects on cognition and physical performance. Studies evaluating the association of serum vitamin D levels in longevity presented different results, possibly due to the heterogeneity of the populations studied. Gschwind et al. somehow addressed this aspect by showing that the association between 25(OH)D and mobility was more pronounced in less vulnerable elderly people [36]. Mathei et al. evaluated the elderly over 85 years of age and found no association between balance, gait velocity and manual grip strength with 25(OH)D [37]. Formiga et al. showed an association of 25(OH)D < 10 ng/ml and worse performance in ADL and gait [31]. Skalska et al. found no association with handgrip strength but showed that cognitive function and balance were associated with serum 25(OH)D in a group with 50% of the elderly with a history of falls [38]. We observed that the chance of independence in IADL increases with the level of 25(OH)D and those in the intermediate range of 25(OH)D had 2.5 times better performance in verbal fluency and in physical performance of grip strength palmar (2.3 times better) and in the sit and stand test (3 times better) compared to those with low 25(OH)D levels. Interestingly, those in the upper tertile of 25(OH)D did not present better performance in FV, palmar grip strength and in the sit stand up test. In this tertile, 61% of the cases used vitamin

D supplementation and even so, they continued to have low functional performance. Thus, in our patients, this vitamin D supplementation may have placed the individuals at a higher 25 (OH)D level, however, it did not reflect in the functional performance, except for the IADL. However, our study design does not allow causal inferences and in addition we lack data on the types, dosage and reason for indication of vitamin D supplementation for more detailed analyzes. However, we observed that the serum 25(OH)D is an indicator of disability risk. It is possible that simply reaching levels of 25 (OH) D > 22 ng/ml, with the use of supplements, is insufficient to overcome this risk. In the present study, we found no interaction between eGFR and 25(OH)D levels in relation to their effects on functional capacity, although a larger study may be useful for a better understanding of this interrelation.

This study has some limitations. The participants did not perform a complete renal evaluation to definitively exclude the presence of chronic kidney disease; however, based on clinical signs and symptoms and medical records review, we can assume that the vast majority of those with decreased levels of eGFR have had this decline due to the aging process. There are other factors that influence functional capacity, such as regular physical activity, pain, balance, psychological motivation, social environment and built environment, which were not addressed in this study. The cross-sectional study design does not allow a more potent investigation of the causal associations between renal function, 25(OH)D and functional aspects. The number of elderly may have been relatively small for the associations surveyed. Finally, as we evaluated only independent adults in the community, without major disabilities, this may have made the group less likely to find the associations investigated. On the other hand, as strengths, this study evaluated a considerable sample of independent, community-dwelling elderly with an approach to different aspects of functional capacity such as cognition, ability to perform daily tasks and physical performance. In addition, we used a more accurate measure than previous studies to estimate GFR, including serum creatinine and cystatin C.

In conclusion, we found that age-related decline in renal function impairs the ability to perform activities for community life (according to IADL assessment) but we did not observe any influence on specific domains of cognition and physical performance. Low serum level of 25 (OH) D appears to be a marker of greater risk of functional decline than eGFR measurement in independent community-dwelling oldest old.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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