ClinicoEconomics and Outcomes Research
Dovepress
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ORIGINAL RESEARCH

Malnutrition Prevalence and Burden on Healthcare Resource Use Among Spanish Community-Living Older Adults: Results of a Longitudinal Analysis

This article was published in the following Dove Press journal:
ClinicoEconomics and Outcomes Research

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Purpose: Little is known about the economic burden that malnutrition or its risk imposes on community-dwelling older adults. Using cross-sectional and longitudinal analyses, we assessed the impact of malnutrition risk on healthcare utilization and costs in a cohort of older adults living in Spanish community.

Patients and Methods: Data from 1660 older (range 66–98 years), community-living adults participating in the Toledo Study on Healthy Ageing, waves 2 (year 2011–2013) and 3 (year 2015), were analyzed. Nutritional status categories were defined according to the Global Leadership Initiative on Malnutrition (GLIM) criteria, using a two-step approach. First, screening for malnutrition risk. Once positive, individuals were classified as malnourished according to some phenotypic (body mass index, grip strength, and unintentional weight loss) and etiologic (disease burden/inflammation and reduced food intake or assimilation) criteria. Outcomes assessed included healthcare resources (hospital admissions, number of hospitalizations, length of hospital stay per hospitalization, and number of medications).

Results: Fifteen percent of the population was found to be at risk of malnutrition, while 12.6% was malnourished. Overall, patients from both groups were older, had lower functional status, and had more comorbidities compared to well-nourished counterparts ($p<0.05$). Results of our cross-sectional analysis showed that being at-risk/malnourished was associated with greater medication utilization, higher rates of hospital admission and longer stays, and higher hospitalization costs. However, when adjusting for covariates, malnutrition/risk was associated only with higher hospitalization costs (range: 11–13%). Longitudinal analysis results indicated that malnutrition/risk was significantly associated with more frequent hospitalizations, longer lengths of stay, higher hospitalization costs, and polypharmacy at follow-up.

Conclusion: Malnutrition or its risk, found in over one of four older adults in the Toledo community, was associated with higher healthcare resource use and increased costs. Such findings suggest that malnutrition risk-screening for older adults, and provision of nutrition counseling and care when needed, hold potential to improve their health and to lower costs of care in the Spanish healthcare system.

Keywords: malnutrition prevalence, healthcare resource use, costs, oral nutritional supplements, ONS, older adults, community, Spain

Introduction

With older age, a common challenge is declining nutritional status, which is associated with effects of chronic diseases and their treatment medications on appetite and on nutrient utilization, along with socioeconomic limits such as inadequate food access, preparation abilities, and unaffordability.[1] Older adults

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are a growing segment of the population in most countries,[2] so malnutrition risk is likewise a growing concern. Despite guidelines on nutrition screening and care for older people,[3] poor nutritional status is too often overlooked or undertreated[4,5] and can result in worse health outcomes and higher treatment costs. Healthcare costs of disease-related malnutrition in older people are substantial[6] and are expected to rise even higher as the proportion of older people in the population increases.

Malnutrition or its risk, notably undernutrition in this study, refers to a state resulting from lack of uptake or intake of nutrition causing altered body composition (decreased body mass and body cell mass), leading to diminished physical and mental function and impaired outcome from disease.[7] Negative consequences of poor nutritional status on older adults in hospitals have long been recognized for clinical,[8,9] functional,[10] and economic[11,13] outcomes. By contrast, data are generally more limited for older adults living in the community.[1,4,14-16] While studies of healthcare costs for community-living adults are gradually emerging,[17–20] some of these studies included younger populations,[17–19] and others were specific to nursing home populations.[20] Additionally, such studies generally use cross-sectional study designs, which cannot predict longer-term consequences of poor nutritional status on patient health and economic outcomes.

We therefore sought to increase the knowledge base about the nutritional status of older, community-living adults in Spain. Our research used a longitudinal study design to explore the effect of poor nutritional status on health and economic outcomes. Nutritional status categories were defined according to the Global Leadership Initiative on Malnutrition (GLIM), which aim to standardize the assessment of malnutrition status by adopting global consensus criteria so that malnutrition prevalence, interventions and outcomes may be compared throughout the world.[21] We hypothesized that at-risk/malnourished subjects would experience higher healthcare resource use and greater costs than their well-nourished counterparts. We specifically assessed use of healthcare resources (hospital admissions, number of hospitalizations, length of hospital stay per hospitalization, and number of medications).

Patients and Methods

Patient Demographics and Description

Our analysis used data from the Toledo Study on Healthy Ageing (TSHA). TSHA is a population-based longitudinal study containing information on adults ≥ 65 years who were institutionalized (2% of the whole sample) or community-dwelling (approximately 98% of the surveyed subjects) in the province of Toledo, Spain. TSHA study findings have been reported elsewhere.[22,23] The study was approved by the Ethical Review Board of the Hospital Virgen del Valle (Toledo) and the Hospital Universitario de Getafe. Participants provided informed consent for the original study by signing a consent form, while a waiver of consent was used for this analysis.

In our present analysis, we used baseline data from individuals participating in TSHA wave 2 (N=2336) and collected between 2011 and 2013. Longitudinal outcomes were taken from the wave 3 data collection (year 2015). Of participants from wave 2 (N=2336), nearly 80% were still alive in wave 3 (N=1844); 264 had died, but only 228 could be followed in wave 3 for other reasons. The mean follow-up time for all eligible participants was 3.18 years (165 weeks).

Nutritional Status, Hospitalization Outcomes, and Other Measures

For this study, nutritional status categories (well-nourished (WN), at malnutritional risk (AMR) or malnourished (MN)) were defined using published criteria,[21] and by applying a two-step approach. In the first step, we screened individuals for malnutrition risk using the Mini-Nutritional Assessment-Short Form (MNA-SF),[24] and classified individuals as either WN or AMR. Those considered AMR were assessed for malnutrition and diagnosed as MN if they met at least one etiologic and one phenotypic criterion from the list below:

Phenotypic criteria

a) Body mass index (BMI), (weight in kilograms (kg)/square of height in meters (m)), below 20 kg/m^2 when the individual is younger than 70 years old or BMI below 22 kg/m^2 when the age is equal to or higher than 70 years old.
b) Non-volitional weight loss, defined as unintentional weight loss of, at least, 5% during the previous six months.
c) Reduced handgrip strength, defined as being below 30.4 kg for men or 19.8 kg for women, as a supporting measure of reduced muscle mass.

Etiologic criteria

d) Reduced food intake or assimilation, as assessed by MNA-SF and the questions about protein-intake of the PREDIMED questionnaire.[25]

e) Disease burden or inflammation, including heart failure, dementia, malignant disease, chronic obstructive pulmonary disease, congestive heart failure, chronic kidney disease, and diabetes.

After applying nutrition status criteria to the original study sample, we only included individuals with complete data for all variables (N=1660, Table 1).

For hospitalization outcomes, we used three measures: (i) having been admitted to hospital and stayed overnight; (ii) number of hospitalization episodes during the previous 12 months; and (iii) mean length of stay per hospital admission, in days. In order to estimate hospitalization costs, we used data from each survey respondent during the previous 12 months (for the cross-sectional analyses) and during the follow-up period (for the longitudinal analyses) from hospital clinical records and we subsequently estimated the cost per person and per year in Euros (€). The unit cost for each Diagnostic Related Group (DRG), obtained from a national data source (National Ministry of Health, Consumption and Social Wellbeing),[26] was multiplied by the number of times subjects were admitted to hospital for each DRG. All costs were expressed in 2015 Euros. Moreover, the number of medications taken daily, as self-reported and checked with medical records, was also used as an outcome measure in the current analysis. All the aforementioned outcomes were measured at baseline (wave 2) for cross-sectional analysis and at follow-up (wave 3) to accommodate the longitudinal analysis.

Other factors were also included, such as depression status (Geriatric Depression Scale, GDS, score ≥6),[27] polypharmacy as daily use of ≥5 medications (considered a hospital-related outcome) and frailty by the Frailty Trait Score (FTS).[22] We also used the Charlson Comorbidity Index (CCI), categorized into three different groups:[6,28] i) no comorbidity if the score equaled zero; ii) low-medium comorbidity if the Charlson score was 1 or 2; and iii) high comorbidity if the score was ≥3.

Statistical Analyses

Summary statistics were presented as mean (± standard deviation) for continuous variables and as number and percent for binary variables. Differences between groups were tested via Mann–Whitney or Chi-square test, as appropriate depending on data distribution. Given the substantial proportion of zeros within the number of hospital admissions (and number of hospitalizations, length of stay, and hospitalization costs) and number of medications, two-part regression models were run for the aforementioned

Table 1 Summary Statistics for the Total Sample and by Nutritional Status at Baseline (Wave 2)

Variables	Whole Sample (N = 1660)	Well Nourished (N = 1203)	Malnutrition Risk (N = 248)	Malnourished (N = 209)	Comparison of Means
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	p-value
Age	75.61 ± 6.29	74.92 ± 6.06	75.35 ± 5.92	79.85 ± 6.41	0.000***
Gender: female (%)	55.06	50.96	70.16	60.77	0.000***
Frailty Trait Scale (FTS)	41.27 ± 15.21	38.16 ± 14.18	46.11 ± 14.21	53.45 ± 14.51	0.000***
Frailty by the FTS, (%)	19.04	14.88	31.85	51.67	0.000***
Charlson Comorbidity Index (%)					0.000***
No comorbidity (0)	45.12	49.87	35.88	28.71	
Medium-low (1–2)	37.17	36.66	39.52	37.32	
High (≥3)	17.71	13.47	24.60	33.97	
Depression (%), GDS ≥6	14.82	8.31	29.84	34.45	0.000***
Number of medications	5.07 ± 3.04	4.46 ± 2.82	6.53 ± 3.00	6.81 ± 3.09	0.000***
Polypharmacy (%), (≥5 medications/day)	52.83	44.14	75.81	78.47	0.000***
Hospital admission (%)	22.23	12.44	20.16	30.70	0.000***
Number of hospital admissions, if admitted	1.38 ± 0.86	1.28 ± 0.63	1.58 ± 1.35	1.51 ± 0.91	0.000***
Length of stay, in days, if admitted	9.59 ± 13.24	7.94 ± 10.26	12.00 ± 19.62	13.27 ± 14.30	0.000***
Cost of hospitalization (in 2015€), if admitted	1892.74 ± 1982.07	1755.61 ± 1738.26	2132.11 ± 2504.12	2120.45 ± 2166.80	0.000***

Note: ***p<0.01.
Abbreviations: SD, standard deviation; FTS, Frailty Trait Scale; GDS, Geriatric Depression Scale.

outcomes. Separate analyses were performed for cross-sectional and longitudinal analysis. The former was used to assess any association between nutritional status and healthcare resource measures within the same time point. The latter was used to evaluate whether nutritional status predicted healthcare use at follow-up (about 3 years), taking the values of the independent variables at baseline (wave 2), and the outcome in the following wave (wave 3).

We used a two-part regression model in which a binary choice model is fit for the probability of observing a positive-versus-zero outcome.[29] Then, conditional on a positive outcome, an appropriate regression model is fit for the positive outcome. The two parts were: (1) a logit model for the binary response variable (first stage), where a value of 1 was assigned if the individual was admitted to hospital at least once or used at least one medication daily versus a value of 0 if the patient had no hospitalizations or used no medications, and (2) a model for the outcome variable that depended on the binary response (admitted to hospital/taking any medications).[29] After first-stage analysis using logit estimation techniques, the second stage involved a Generalized Linear Model (GLM) with Poisson distribution for number of hospital admissions, length of stay, and number of medications, and a gamma distribution and log-link if costs of hospitalization were assessed.[30] In these models, nutritional status was the only explanatory variable included.

In another regression model, age and gender were added, as well as 3 other categories: (1) comorbidity level by CCI; (2) being depressed according to the GDS; and (3) polypharmacy. In a third regression model, frailty by FTS was also incorporated. All analyses were performed using Stata SE version 15.0, and p values ≤ 0.05 were considered statistically significant.

Results

Summary Statistics

Characteristics of the full study population and characteristics by nutritional status at baseline (wave 2 of the TSHA), as well as healthcare resource use, are shown in Table 1. The mean age was 76 years old and 55% were females. With respect to the measurement of frailty, the mean FTS score was 41 points. As many as 45% of participants reported having no comorbidities, and the mean GDS score was 3.5 points, respectively. Of the whole sample, 53% were identified as polypharmacy users, with 5 as the mean number of medications taken on a regular basis.

Per nutritional status classification criteria, 72.5% of the whole sample were classified as WN, whereas 15% were identified as ARM and the remaining 12.6% were categorized as MN. Several differences were detected between the two groups. Of note, ARM and MN subjects were older than their WN counterparts (79.85 and 75.35 vs 74.92 years, p<0.001). Also, AMR and MN subjects had worse frailty status and were more likely to be depressed, while the WN group was more likely to include females and have no comorbidities.

In the overall sample, 22% of the individuals had been admitted to the hospital in the previous 12 months. Among admitted individuals, the mean length of stay was higher than 9 days and the mean hospitalization cost was nearly €1900. The proportion of patients who used more than 5 medications on a daily basis was higher in the AMR and MN groups compared to their WN counterparts (75.81% and 78.47% vs 44%, p<0.001). The AMR and MN patients were also more likely to have been admitted to the hospital than WN patients (20.16% and 30.70%, respectively, vs 12.44%, p<0.001), had longer lengths of stays (4 and 5 more days, on average per year, respectively, p<0.001), and higher annual hospitalization costs by approximately €400 (p<0.001).

Regression results for Cross-Sectional and Longitudinal Analyses

Cross-Sectional Analysis

Regression results on the cross-sectional analysis between nutritional status and other independent variables and hospital admission, number of hospitalizations, average length of stay per admission, costs, and number of medications taken during the same wave are reported in Tables 2 and 3.

When nutritional status was the only independent variable included in the analysis (Model 1), being at-risk/malnourished was associated with an increase in the risk of being admitted to the hospital (OR=1.511 and OR=2.381 compared to WN individuals, Table 2). In model 1, AMR status was associated with a significantly longer average length of stay by 0.584 days (p<0.05). Further, being AMR was associated with increased costs for hospitalization (+19.5%) compared to WN counterparts. On the other hand, compared to WN patients, MN patients had significantly more hospital admissions (1.77 more, on average, per year) and with longer average length

Table 2 Regression Results for the Cross-Sectional Analysis: Hospital Admission Outcomes

Variables	Model 1				Model 2				Model 3			
	Hospital admission risk (OR)	**If admitted, number of hospital admissions in the last 12 months (Coeff.)**	**If admitted, average length of stay per hospital admission (Coeff.)**	**If admitted, average hospital admission costs per hospital stay (Coeff.)**	**Hospital admission risk (OR)**	**If admitted, number of hospital admissions in the last 12 months (Coeff.)**	**If admitted, average length of stay per hospital admission (Coeff.)**	**If admitted, average hospital admission costs per hospital stay (Coeff.)**	**Hospital admission risk (OR)**	**If admitted, number of hospital admissions in the last 12 months (Coeff.)**	**If admitted, average length of stay per hospital admission (Coeff.)**	**If admitted, average hospital admission costs per hospital stay (Coeff.)**
Nutritional status												
At nutritional risk	1.511**	0.210*	0.484**	0.195***	1.252	0.181*	0.412*	0.109**	1.225	0.181*	0.354	0.115**
	(0.245)	(0.110)	(0.243)	(0.158)	(0.220)	(0.107)	(0.229)	(0.131)	(0.216)	(0.103)	(0.217)	(0.135)
Malnourished	2.381***	0.160**	0.568***	0.199***	1.361*	0.0954	0.296*	0.154**	1.294	0.0953	0.250	0.132**
	(0.385)	(0.0763)	(0.164)	(0.132)	(0.253)	(0.0757)	(0.169)	(0.130)	(0.246)	(0.0764)	(0.172)	(0.133)
Age					1.039	−0.171	0.0973	0.0248	1.038	−0.171	0.0615	0.0242
					(0.207)	(0.104)	(0.283)	(0.154)	(0.207)	(0.105)	(0.279)	(0.155)
Age^2					1.000	0.00108	−0.000526	−0.000156	1.000	0.00108	−0.000375	−0.000147
					(0.00128)	(0.000662)	(0.00176)	(0.000994)	(0.00128)	(0.000662)	(0.00173)	(0.000999)
Female					0.721***	−0.158**	−0.346**	−0.165*	0.703***	−0.158**	−0.403**	−0.163
					(0.0906)	(0.0662)	(0.154)	(0.0995)	(0.0891)	(0.0686)	(0.164)	(0.101)
Charlson Index categories												
Medium-low (1–2)					1.527***	0.114**	0.213	0.277**	1.520***	0.114**	0.216	0.277**
					(0.219)	(0.0580)	(0.141)	(0.108)	(0.218)	(0.0580)	(0.142)	(0.108)
High (≥3)					2.070***	0.310***	0.772***	0.495***	2.034***	0.310***	0.725***	0.496***
					(0.354)	(0.0796)	(0.185)	(0.129)	(0.348)	(0.0774)	(0.173)	(0.129)
Depression, according to GDS					1.214	0.0201	0.0247	−0.169	1.151	0.0199	−0.0784	−0.159
					(0.216)	(0.0919)	(0.223)	(0.112)	(0.209)	(0.0856)	(0.193)	(0.113)
Polypharmacy					1.477***	0.0982	0.336	0.181*	1.437**	0.0980	0.251	0.186**
					(0.206)	(0.0709)	(0.211)	(0.0934)	(0.202)	(0.0769)	(0.221)	(0.0943)
Frailty, according to FTS									1.314*	0.000748	0.517**	−0.0347
									(0.204)	(0.0823)	(0.203)	(0.121)
Observations	1660	369	369	376	1660	369	369	376	1660	369	369	376

(*Continued*)

Table 2 (Continued).

Variables	Model 1				Model 2				Model 3			
	Hospital admission risk (OR)	If admitted, number of hospital admissions in the last 12 months (Coeff.)	If admitted, average length of stay per hospital admission (Coeff.)	If admitted, average hospital admission costs per hospital stay (Coeff.)	Hospital admission risk (OR)	If admitted, number of hospital admissions in the last 12 months (Coeff.)	If admitted, average length of stay per hospital admission (Coeff.)	If admitted, average hospital admission costs per hospital stay (Coeff.)	Hospital admission risk (OR)	If admitted, number of hospital admissions in the last 12 months (Coeff.)	If admitted, average length of stay per hospital admission (Coeff.)	If admitted, average hospital admission costs per hospital stay (Coeff.)
Log-pseudolikelihood	−864.63	−471.37	−2,772.78	−3,212.76	−822.11	−464.73	−2,488.33	−3,200.90	−820.54	−464.73	−2,403.93	−3,200.87
AIC		2.57	15.04	17.11		2.57	13.54	17.08		2.58	13.09	17.08
BIC		−2029.90	2144.79	−1968.87		−2001.79	1617.26	−1951.08		−1995.88	1454.37	−1945.22

Notes: Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1: Reference categories: well-nourished, men, no comorbidity, no depression, no polypharmacy: Model 1 includes being at nutritional risk or malnourished: Model 2 adds to Model 1 sociodemographic characteristics (age and gender), the comorbidity severity of individual according to the Charlson Index, which is medium-low if the Charlson Index score is 1 or 2; and high if the Charlson Index score is 3 or higher. Moreover, being depressed is added if the score in the GDS is equal or higher than 6: In Model 2, polypharmacy is also included if the daily number of medications the subject is taking is 5 or more: Model 3 adds this variable to Model 2: frailty status according to the Frailty Trait Score.
Abbreviations: OR, odds ratio; Coeff., coefficient; GDS, Geriatric Depression Scale; FTS, Frailty Trait Scale; AIC, Akaike's information criterion; BIC, Bayesian information criterion.

of stay per admission (0.728 more days [p<0.05]). Furthermore, being MN was associated with 20% higher hospitalization costs compared to WN individuals (p<0.05). However, when the variables of age and gender, comorbidities, depression, and number of medications were included (Model 2), nutritional status did not significantly alter the probability of having hospital admission or increase average length of stay. Still, being MN was associated with 15.4% higher hospital costs. Finally, when frailty was part of the analysis (Model 3), nutritional status was not significantly associated with risk of hospital admission, number of times admitted, or the average length of stay. In contrast, nutritional status was still significantly associated with hospital admission costs. In fact, being malnourished was associated with larger hospitalization costs by 13.2%, compared to WN individuals.

In Model 1, being malnourished was not significantly associated with the risk of taking any medications compared to WN individuals (Table 3), but being AMR was indeed significantly related to the risk of higher polypharmacy (OR=2.96). However, both nutritional status categories, compared to being WN, were significantly associated with the number of medications taken, which increased by 0.409 medications in case of being AMR and by 0.49 if MN (p<0.05). However, if age and gender, comorbidities, and depression were included (Model 2), nutritional status was not associated with the probability of taking any medications. Such non-significant relationship remained in Model 3, when frailty was added to the analysis. But, being AMR or MN were always associated with a higher number of medications taken on a daily basis, which ranged from 0.261 (Model 3) to 0.285 (Model 2) if AMR, and from 0.202 to 0.252 when MN, respectively.

Longitudinal Analysis

For longitudinal analyses, regression results on the association between nutritional status at baseline, as well as other independent variables, on the outcomes at follow-up (hospital admission, number of hospitalizations, average length of stay per admission, costs, and number of medications taken) are shown in Tables 4 and 5.

When nutritional status was the only independent variable included in the analysis (Model 1), being AMR and MN in wave 2 was related to an increased risk of hospital admission in wave 3 by 1.432 and 1.878 OR, respectively (compared to WN individuals, Table 4). Negative nutrition status was also associated with a greater number of

Table 3 Regression Results for the Cross-Sectional Analysis: Medications Use

Variables	Model 1		Model 2		Model 3	
	Medication use risk (OR)	If any medication is taken on a daily basis, number of medications (Coeff.)	Medication use risk (OR)	If any medication is taken on a daily basis, number of medications (Coeff.)	Medication use risk (OR)	If any medication is taken on a daily basis, number of medications (Coeff.)
Nutritional status						
At nutritional risk	2.957**	0.343***	2.358*	0.251***	2.337*	0.232***
	(1.386)	(0.0324)	(1.070)	(0.0318)	(1.055)	(0.0310)
Malnourished	1.756	0.399***	1.533	0.225***	1.494	0.184***
	(0.710)	(0.0331)	(0.577)	(0.0353)	(0.586)	(0.0344)
Age			3.009***	0.0636	3.004***	0.0650
			(0.931)	(0.0411)	(0.929)	(0.0404)
Age^2			0.993***	−0.000318	0.993***	−0.000352
			(0.00196)	(0.000266)	(0.00197)	(0.000261)
Female			2.373***	0.104***	2.353***	0.0861***
			(0.578)	(0.0251)	(0.570)	(0.0249)
Charlson Index categories						
Medium-low (1–2)			2.154***	0.277***	2.146***	0.269***
			(0.603)	(0.0275)	(0.599)	(0.0272)
High (≥3)			1.344	0.427***	1.335	0.409***
			(0.402)	(0.0330)	(0.397)	(0.0325)
Depression per GDS			0.999	0.0826**	0.983	0.0418
			(0.364)	(0.0327)	(0.359)	(0.0329)
Frailty, according to FTS					1.104	0.198***
					(0.388)	(0.0279)
Observations	1660	1579	1660	1579	1660	1579
Log-pseudolikelihood	−319.34	−3805.23	−302.87	−3635.12	−302.83	−3609.01
AIC		4.82		4.62		4.58
BIC		−9330.42		−9626.44		−9671.30

Notes: Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1. Reference categories: well-nourished, men, no comorbidity, no depression: Model 1 includes being at nutritional risk or malnourished: Model 2 adds to Model 1 sociodemographic characteristics (age and gender), the comorbidity severity of individual according to the Charlson Index, which is medium-low if the Charlson Index score is 1 or 2; and high if the Charlson Index score is 3 or higher: Moreover, being depressed is added if the score in the GDS is equal or higher than 8: Model 3 adds to Model 2 the frailty status according to the Frailty Trait Score.

Abbreviations: OR, odds ratio; Coeff., coefficient; GDS, Geriatric Depression Scale; FTS, Frailty Trait Scale; AIC, Akaike's information criterion; BIC, Bayesian information criterion.

hospital admissions, a longer average length of hospital stay, and higher hospitalization costs. These measures increased in MN patients by 0.655 times, 0.714 days, and 29.5% higher costs, respectively. For AMR patients, their nutrition status was significantly related to longer length of hospital stay and the cost of those hospitalizations (+0.513 days and 29.5%, respectively [p<0.05]). However, nutritional status was no longer significant in Model 2 for the odds of being admitted to the hospital, when adjusting for age, gender, comorbidities, depression, and polypharmacy. This trend held in the third regression model. Still, being AMR and MN were significantly related with higher hospitalization costs in the follow-up, which increased by 30% in both nutritional status categories. Moreover, being MN at baseline was significantly associated with longer hospital stays after 3 years of follow-up, which increased by 0.46 (Model 2) and 0.37 (Model 3) days. If AMR at baseline, the number of hospital admissions was higher at follow-up by 0.23 (Model 2) and 0.21 (Model 3) times (p<0.05).

Table 5 shows that, in Model 1, being at-risk in the previous wave was not significantly associated with the risk of taking any medications in the next wave, compared to WN individuals. Nutritional status was indeed

Table 4 Regression Results for the Longitudinal Analysis: Hospitalization Outcomes

Variables	Model 1				Model 2				Model 3			
	Hospital admission risk (OR)	If admitted, number of hospital admissions in the last 12 months (Coeff.)	If admitted, average length of stay per hospital admission (Coeff.)	If admitted, average hospital admission costs per hospital stay (Coeff.)	Hospital admission risk (OR)	If admitted, number of hospital admissions in the last 12 months (Coeff.)	If admitted, average length of stay per hospital admission (Coeff.)	If admitted, average hospital admission costs per hospital stay (Coeff.)	Hospital admission risk (OR)	If admitted, number of hospital admissions in the last 12 months (Coeff.)	If admitted, average length of stay per hospital admission (Coeff.)	If admitted, average hospital admission costs per hospital stay (Coeff.)
Nutritional status												
At nutritional risk	1.432**	0.173*	0.414**	0.295***	1.291	0.206**	0.389**	0.300***	1.268	0.191**	0.350*	0.304***
	(0.214)	(0.0982)	(0.192)	(0.114)	(0.209)	(0.0992)	(0.192)	(0.113)	(0.205)	(0.0969)	(0.182)	(0.113)
Malnourished	1.878***	0.274***	0.539***	0.295***	1.236	0.238**	0.379***	0.299***	1.181	0.214*	0.316**	0.305***
	(0.292)	(0.104)	(0.136)	(0.109)	(0.221)	(0.105)	(0.137)	(0.109)	(0.214)	(0.112)	(0.144)	(0.112)
Age					1.073	0.266**	0.258	0.0808	1.072	0.265**	0.248	0.0787
					(0.199)	(0.116)	(0.216)	(0.123)	(0.198)	(0.115)	(0.212)	(0.123)
Age^2					1.000	−0.00168**	−0.00162	−0.000567	1.000	−0.00168**	−0.00160	−0.000550
					(0.00119)	(0.000748)	(0.00136)	(0.000787)	(0.00119)	(0.000738)	(0.00133)	(0.000784)
Female					0.543***	−0.0835	−0.134	−0.0594	0.531***	−0.0961	−0.168	−0.0550
					(0.0629)	(0.0727)	(0.130)	(0.0787)	(0.0620)	(0.0730)	(0.135)	(0.0801)
Charlson Index categories												
Medium-low (1–2)					1.238*	0.0134	−0.0545	−0.0203	1.232	0.0115	−0.0604	−0.0194
					(0.158)	(0.0734)	(0.130)	(0.0890)	(0.158)	(0.0737)	(0.131)	(0.0889)
High (≥3)					1.476**	0.245***	0.428**	0.100	1.451**	0.241***	0.416***	0.103
					(0.232)	(0.0934)	(0.167)	(0.111)	(0.229)	(0.0926)	(0.162)	(0.111)
Depression per GDS					0.962	−0.113	−0.0330	−0.0777	0.916	−0.130	−0.0809	−0.0713
					(0.162)	(0.104)	(0.197)	(0.103)	(0.158)	(0.100)	(0.181)	(0.102)
Polypharmacy					1.817***	−0.0810	0.0721	−0.00330	1.778***	−0.0955	0.0305	0.000403
					(0.227)	(0.0787)	(0.166)	(0.0853)	(0.225)	(0.0802)	(0.173)	(0.0865)
Frailty, according to FTS									1.277*	0.119	0.326**	−0.0332
									(0.186)	(0.0897)	(0.165)	(0.0923)
Observations	1660	369	369	369	1660	369	369	369	1660	369	369	369
Log-pseudolikelihood	−993.35	−824.05	−3606.18	−4504.21	−945.75	−813.68	−3469.56	−4502.27	−944.34	−812.47	−3423.24	−4502.23
AIC		3.41	14.88	18.28		3.40	14.35	18.31		3.40	14.16	18.31
BIC		−2523.7	2560.92	−2743.33		−2501.16	2330.97	−2703.80		−2497.40	2244.50	−2697.69

Notes: Robust standard errors in parentheses: ***p<0.01, **p<0.05, *p<0.1: Reference categories: well-nourished, men, no comorbidity, no depression, no polypharmacy: Model 1 includes being at nutritional risk or malnourished at baseline: Model 2 adds to Model 1 sociodemographic characteristics (age and gender), the comorbidity severity of individual according to the Charlson Index, which is medium-low if the Charlson Index score is 1 or 2; and high if the Charlson Index score is 3 or higher. Moreover, being depressed is added if the score in the GDS is equal or higher than 6: In Model 2, polypharmacy is also included if the daily number of medications the subject is taking is 5 or more: Model 3 adds to Model 2 the frailty status according to the Frailty Trait Score.

Abbreviations: OR, odds ratio; Coeff, coefficient; GDS, Geriatric Depression Scale; FTS, Frailty Trait Scale; AIC, Akaike´s information criterion; BIC, Bayesian information criterion.

Table 5 Regression Results for the Longitudinal Analysis: Medications Use

Variables	Model 1		Model 2		Model 3	
	Medication use risk (OR)	If any medication is taken on a daily basis, number of medications (Coeff.)	Medication use risk (OR)	If any medication is taken on a daily basis, number of medications (Coeff.)	Medication use risk (OR)	If any medication is taken on a daily basis, number of medications (Coeff.)
Nutritional status						
At nutritional risk	2.002	0.328***	1.462	0.234***	1.423	0.221***
	(1.063)	(0.0371)	(0.734)	(0.0355)	(0.724)	(0.0352)
Malnourished	–	0.344***	–	0.163***	–	0.145***
		(0.0411)		(0.0435)		(0.0433)
Age			1.824	0.0920*	1.792	0.0870*
			(0.896)	(0.0494)	(0.878)	(0.0482)
Age^2			0.997	−0.000520	0.997	−0.000502
			(0.00316)	(0.000320)	(0.00315)	(0.000312)
Female			2.444***	0.0616**	2.392**	0.0494*
			(0.822)	(0.0280)	(0.832)	(0.0281)
Charlson Index categories						
Medium-low (1–2)			4.206***	0.278***	4.175***	0.273***
			(1.940)	(0.0305)	(1.931)	(0.0304)
High (≥3)			1.514	0.408***	1.476	0.390***
			(0.684)	(0.0359)	(0.685)	(0.0359)
Depression per GDS			1.160	0.117***	1.101	0.0851**
			(0.656)	(0.0372)	(0.651)	(0.0377)
Frailty, according to FTS					1.450	0.140***
					(0.975)	(0.0327)
Observations	1660	1584	1660	1584	1660	1584
Log-pseudolikelihood	−183.68	−3166.13	−168.76	−3034.15	−168.58	−3023.41
AIC		4.94		4.74		4.73
BIC		−7255.82		−7476.84		−7491.17

Notes: Robust standard errors in parentheses: ***p<0.01, **p<0.05, *p<0.1: Reference categories: well-nourished, men, no comorbidity, no depression: Model 1 includes being at nutritional risk or malnourished at baseline: Model 2 adds to Model 1 sociodemographic characteristics (age and gender), the comorbidity severity of individual according to the Charlson Index, which is medium-low if the Charlson Index score is 1 or 2; and high if the Charlson Index score is 3 or higher: Moreover, being depressed is added if the score in the GDS is equal or higher than 6: Model 3 adds to Model 2 the frailty status according to the Frailty Trait Score.
Abbreviations: OR, odds ratio; Coeff, coefficient; GDS, Geriatric Depression Scale; FTS, Frailty Trait Scale; AIC, Akaike´s information criterion; BIC, Bayesian information criterion.

significantly associated with the number of medications taken, which increased significantly for both AMR and MN groups (0.40 and 0.45 more medications taken daily, respectively [p<0.05]). Nutritional status at baseline was still associated with the number of medications taken when age, gender, comorbidities, and depression were included (Model 2); this trend was maintained in subsequent regression models (Model 3). Patients who were AMR at baseline took more medications on a daily basis at follow-up (0.26 [Model 2] and 0.25 [Model 3] more medications (p<0.05)). For MN older adults, the increase in number of daily medications was slightly smaller than among AMR subjects but still significant (0.18 and 0.16 more medications, respectively; p <0.05).

Discussion

We found malnutrition or its risk in over one of four (27.5%) older adults living in the Toledo community; such malnutrition was associated with higher use of healthcare resources and increased costs. These findings suggest that malnutrition risk-screening for older adults, and provision of nutrition counseling and care when needed, hold potential to improve health outcomes for older people and can lower overall costs of care in the Spanish healthcare system. More specifically, results from our study suggested that hospitalization costs can be up to €400 higher for ARM and MN older adults than for those who were WN, consistent with prior findings for older, community-living adults.[16] Our findings of increased use of healthcare resources by ARM and MN adults were also generally consistent with findings from an observational study including somewhat younger community-dwelling adults in the United Kingdom.[19]

In the cross-sectional analysis, poor nutritional status was related to higher hospitalization costs, which increased by about 13–20% among older MN adults and by almost 11–20% if AMR, depending on the covariates included. Only when nutritional status was the unique independent variable, was being NRM significantly and positively associated with the probability of being admitted to hospital, having a longer hospital stay, and using more medications. Moreover, in longitudinal analyses, nutritional status at baseline was significantly related to increasing use of healthcare resources at follow-up. More specifically, being AMR or malnourished was associated with higher hospital-related costs due to hospitalization by 30%. Comparing our results to other studies, Meijers et al[20] found that malnourished institutionalized people had, on average, higher costs by €10,000 per year per person. However, their analysis was for people living in nursing homes and focused on the additional costs for managing malnutrition. On the other hand, Guest et al[16] found that 6-month healthcare costs were 47% higher for malnourished adults. However, only 60% of the subjects were older than 65 years old, so the numbers are not fully comparable to ours. Finally, Martínez-Reig et al[6] used an adjusted analysis, hospital admission costs increased by nearly €500 among malnourished older people. Although this study might be generally comparable to ours, those authors evaluated frail older adults, who likely need more healthcare services than non-frail individuals. They also used a different nutritional assessment tool, and the study was only a cross-sectional analysis. Additional studies performing longitudinal analyses of associations between nutritional status and healthcare use are needed to confirm our findings.

Of interest in our study was the finding that when frailty entered the analysis, the association between nutritional status and some of the outcomes (hospital admission-related outcomes) was weakened, suggesting that frailty may independently affect other variables traditionally related to healthcare resource use, such as age or clinical health status.[31–34] Malnutrition and frailty are two important geriatric syndromes in community-dwelling older adults,[35] which significantly impact independent living, quality of life, and healthcare consumption, and both have a clear nutrition-related component. Moreover, malnutrition is a cornerstone in the management of frailty,[36] since it is central to the clinical transition from frailty to disability, and, as a consequence, considered one of the most important factors in disability prevention.

This study has several limitations. First, the study inherits the limitations of the original THA study,[22,23] and the interpretation of our findings as causative should be made with caution. However, this study is the first one that used a longitudinal analysis approach to look at the impact of malnutrition status on healthcare resource use over 3 years. It is worth mentioning that the observed significant association between at-risk/malnutrition and healthcare use and costs remained significant in the models even after adjusting for multiple covariates, including comorbidity severity. The relevance of this finding is two-fold: the percentage of the association remaining in the adjusted models is independent of the adjusting variable; but, at the same time, part of this association is accounted by the adjusting variable (the percentage of diminishing odds ratio/coefficient). We also believe that when the covariates that could potentially account for the association between the variables of interest (exposure and outcome) are carefully assessed, a true association and probably a causal relationship between nutritional status and healthcare use/costs could be demonstrated. A second limitation comes from using a non-validated criteria to identify malnutrition and its risk by using a recent consensual definition, the GLIM criteria.[21] Future research is needed to validate our findings. Third, we did not account for other additional healthcare resources, such as emergency department use, primary care and specialist visits, and medication costs. However, we relied on DRG information which include the mean total costs related to any hospitalization, including diagnostic and laboratory tests or medications used during the hospital stay. Additionally, the costs accounted for in our analysis consist of the main drivers of healthcare costs. However, future research could benefit from including all healthcare and non-healthcare related costs, such as social and informal care provided by relatives or friends. Finally, the base case analysis does not account for variability among different sub-populations in the three study groups via robustness checks across specific subgroups (ie, different age groups or gender);

therefore, future studies can employ sensitivity analysis to account for variability in measures assessed.

Regardless of these limitations, the results of this first-of-its-kind study provide evidence around the short- and long-term effect of malnutrition on healthcare resource use of community-dwelling older adults which could be used to inform healthcare policies and stakeholders communication in Spain. Specifically, the results of this study highlight the importance of malnutrition screening/assessment among older adults and provide a call to action for primary care and community health clinicians who should integrate nutrition protocols for evaluation nutritional issues to help improve clinical outcomes for older people.[37] Moreover, the adoption of effective nutritional interventions, such as oral nutritional supplements (ONS), in at-risk/malnourished older adults living in the community, may have an important impact in improving health outcomes and reducing healthcare costs.[16] Nutrition interventions have been found to be effective in improving anthropometrics (body weight), nutritional and functional status, energy and protein intake, and muscle strength (handgrip strength) among community-dwelling adults.[30] A recent study evaluating a nutrition-focused program with screening, education, and ONS treatment of at-risk/malnourished community-dwelling adults receiving healthcare services at home was found to reduce 90-day hospitalizations, overall healthcare resource use (inclusive of hospitalizations, emergency department and outpatient clinic visits) and generate total savings of over $2.3 million.[38]

In conclusion, we call for government leaders and policy-makers to devise strategies that reduce malnutrition, as guided by the World Health Organization.[39] Such actions must increase attention to healthy nutrition throughout life, including the older adult population living in the community. Healthcare professionals can harness the benefits of optimal nutrition to ensure a healthy aging process and to maximize healthy life-years by preventing all forms of malnutrition and frailty among older people.

Data Sharing Statement

The TSHA dataset can be made freely available upon request through its website (info@estudiotoledo.com).

Ethics Approval and Consent to Participate

Ethical approval was approved by the local Ethical Review Board of the Hospital Virgen del Valle (Toledo) and the Hospital Universitario de Getafe. Participants provided informed consent for original study, while a waiver of consent was used for this analysis.

Acknowledgments

We thank C. Hofmann & Associates for editorial support with the manuscript.

Author Contributions

All authors contributed to data analysis, drafting or revising the article, gave final approval of the version to be published, and agree to be accountable for all aspects of the work.

Funding

The Toledo study was funded by grants from the Spanish Ministry of Economy, Industry and Competitiveness, co-financed by the European Regional Development Funds (RD120001/0043) and the Centro de Investigación Biomédica en Red en Fragilidad y Envejecimiento Saludable-CIBERFES (CB16/10/00464). Financial support for this analysis was provided by Abbott Laboratories, Chicago, Illinois, USA.

Disclosure

L Rodríguez-Mañas has received consultancy fees from Abbott. R Rueda and S Sulo are employees and stockholders of Abbott. The authors report no other conflicts of interest in this work.

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