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Original Communication

Assessment of Nutritional Status and Vitamin B12 Levels Among Older Adults in a Geriatric Outpatient Clinic: A Cross-Sectional Study

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Abstract

Background: Aging is a multidimensional process influenced by a range of physiological and non-physiological factors. This study aimed to evaluate nutritional status and vitamin B12 levels and to examine the prevalence and risk of malnutrition and vitamin B12 deficiency among older patients attending a geriatric outpatient clinic. **Methods:** This cross-sectional study included 120 patients aged 60 years and older who attended a geriatric outpatient clinic. Nutritional status was assessed using anthropometric measurements and the mini-nutritional assessment (MNA) scale, and biochemical data were obtained from medical records. Demographic information was collected through face-to-face interviews. **Results:** Among participants, 14.2% were malnourished, 62.5% were at risk of malnutrition, and 23.3% were normal. Bivariate analysis showed that older age (81–90 years: 40% vs. 60–70 years: 6.5%; p = 0.001) and marital status (divorced/widowed: 18.8% vs. married: 11.2%; p = 0.020) were associated with nutritional status. Nutritional status was also significantly associated with monthly income (p = 0.001) and educational level (p = 0.018), but malnutrition was not uniformly distributed across income and education categories. Thus, these results should be interpreted with caution. The results also showed that lower serum albumin levels (p = 0.014) and hemoglobin levels (p = 0.009) may indicate poor nutritional status among older adults. The Firth-penalized binary logistic regression model showed that widowhood (adjusted odds ratio [AOR] = 4.12, 95% confidence interval [CI]: 1.10–15.47; p = 0.036) and illiteracy compared with participants with <4 years (AOR = 0.22, 95% CI: 0.05–0.97; p = 0.046) and ≥4 years of education (AOR = 0.25, 95% CI: 0.07–0.85; p = 0.026) were associated with higher odds of being at risk of malnutrition or malnourished, while diabetes status was not significantly associated with vitamin B12 deficiency after adjustment. **Conclusions:** This study demonstrated malnutrition and vitamin B12 deficiency among older adults, which may pose a significant public health issue affecting a large portion of the geriatric population and highlighting the importance of regular nutritional screening in older adults.

Keywords: older adults; mini-nutritional assessment; vitamin B12; diabetes mellitus; nutritional status

1. Introduction

People over 60 years old are growing at an astonishing rate because improved health and medical progress have increased life expectancy. Globally, around 1 billion people were over 60 years of age in 2019, and this number is expected to rise to 1.4 billion in 2030 and 2.1 billion by 2050 [1]. In humans, aging is a multidimensional process accompanied by a range of physiological and non-physiological factors. Physiological factors include loss of appetite, also referred to as anorexia of aging, due to adverse changes in anorectic signaling such as leptin, orexin A, and cholecystokinin [2,3,4]; sensory impairments, such as reduced taste perception or olfactory dysfunction; delayed gastric emptying and disrupted gastrointestinal motility, contributing to the functional deterioration of the gastrointestinal tract [2,4]; reduced physical activity; reduced basal metabolic rate and energy expenditure; difficulties in chewing due to loss of teeth, decreased lean body mass, and bone density [5,6]. Various non-physiological factors, such as psychological factors including depression and cognitive decline [7], and economic and social factors such as restricted or no income and social isolation, are potentially increasing the risk of malnutrition and its complications [8].

In older adults, malnutrition is defined as a "defective or inadequate nutritional status, characterized by poor appetite, inadequate diet, loss of muscle strength, and weight loss" [9]. A multinational study by Kaiser and colleagues [10], using the mini-nutritional assessment (MNA), a recommended tool for assessing nutritional status, found that 13.8% of older individuals in nursing homes were malnourished and 54% were at risk of malnutrition. This condition, which is becoming increasingly prevalent in geriatric patients, results from a combination of insufficient intake and increased physiological demands. Therefore, ensuring adequate nutrient intake is crucial to maintaining good health, especially in older adults.

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Persistent undernutrition in older adults is linked to subclinical deficiencies, particularly of vitamins B6, B12, and folate, which often go undetected because reference ranges vary, allowing many borderline or subclinical cases to remain unnoticed [11]. Vitamin B12 is an essential micronutrient required for DNA and RNA synthesis, erythropoiesis, myelin production, and neurological function [12]. Deficiency can cause a range of clinical manifestations, including megaloblastic anemia, optic and peripheral neuropathy, spinal cord degeneration, memory loss, and various mental health disorders [13]. Older adults are especially vulnerable to vitamin B12 deficiency due to the high prevalence of food-cobalamin malabsorption associated with atrophic gastritis, as well as the increasing incidence of pernicious anemia with age [14]. Early identification and treatment of vitamin B12 deficiency are possible if low and high cutoff values define deficiency and insufficiency, respectively, reducing deficiency-related health risks and improving population health outcomes through targeted public health strategies. Nutrition and health are often overlooked in older adults, although timely intervention can prevent weight loss in at-risk individuals. Research lacks precise estimates of undernutrition in this group. Assessing nutritional status is key to developing databases that support targeted programs and policies. Although the MNA is a recommended tool for assessing nutritional status in older adults, it does not detect micronutrient deficiencies such as vitamin B12. Thus, this study aimed to evaluate nutritional status and vitamin B12 levels and examine the prevalence and associated risk of malnutrition and vitamin B12 deficiency among older patients attending a geriatric outpatient clinic.

2. Materials and Methods

2.1 Study Design and Population

This cross-sectional study was conducted at the outpatient geriatric clinic of National Guard Hospital in Riyadh. Participant recruitment and data collection took place from September 2020 to March 2021. The clinic serves a fairly diverse older population with a wide range of clinical and demographic characteristics.

2.1.1 Inclusion Criteria

We included individuals aged 60 years or older who could provide informed consent and had not participated in any intervention that could interfere with nutritional status assessment. Participants with chronic comorbidities were eligible. Comorbidity burden was assessed using the Charlson comorbidity index (CCI).

2.1.2 Exclusion Criteria

Individuals with a history of any disease that may cause malabsorption of vitamin B12, such as celiac disease, Crohn's disease, chronic hepatic diseases, pernicious anemia, or gastritis (endoscopy diagnosis), as well as patients with small-intestinal problems, such as inflammatory bowel disease, or those who have undergone small-intestinal surgeries, and patients with cancer were excluded.

2.1.3 Sample Size Estimation

The required sample size was calculated using the formula.

$$n = \frac{Z^2 \times P\,(1 - P)}{d^2}$$

where n denotes the required sample size, Z represents the standard normal deviate at a 95% confidence level (Z = 1.96), P denotes the estimated population proportion (p = 0.5), and d represents the margin of error, set at 9% (d = 0.09). Since the present study aimed to evaluate nutritional status and vitamin B12 levels and examine their prevalence and associated risk, we calculated the sample size using a conservative population proportion rather than a single primary outcome (endpoint). This yielded a minimum required sample size of 119 participants.

A total of 186 participants were enrolled in this study. Of these, 10 patients declined to participate; 2 were excluded for not meeting the inclusion criteria, and 54 were excluded because their files lacked a B12 analysis. The final number of study participants was 120. Fig. 1 presents the flowchart of participant selection and study design. Comprehensive information about the study was provided to all individuals who met the inclusion criteria. The objectives and scope of the research were clearly explained, along with a detailed overview of the questionnaires and the anticipated duration of the interview process.

2.2 Study Questionnaire

A trained researcher collected data face-to-face using a questionnaire the research team designed during routine visits to the geriatric outpatient clinic. A pilot study of 25 participants (results not reported in the study) was conducted to confirm the reliability and validity of the questionnaire and to evaluate the understanding of the participants of the questions. To ensure content validity, a panel of experts in the field reviewed the clarity of the questionnaire items. After reviewing the items and making necessary modifications, the final questionnaire was approved, which included questions based on the sociodemographic characteristics of the participants, their nutritional and vitamin B12 status, and medication history. In addition, CCI was used to predict mortality.

2.2.1 Demographic Characteristics

This section included questions on demographics, including gender, age, marital status, occupation, income, education, residential status (alone, with family/friends, in a nursing home), and smoking status. Physical measures

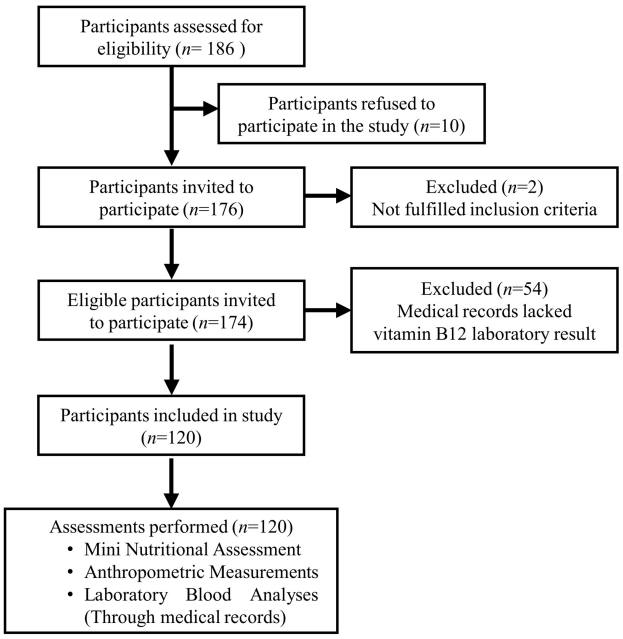


Fig. 1. Flowchart of study participant selection and study design.

such as height, weight, and calf circumference were also obtained following standardized procedures. We measured height using a stadiometer to the nearest 0.1 cm and weight using a weighing scale to the nearest 0.1 kg. We calculated body mass index (BMI) as weight in kilograms divided by the square of height in meters (kg/m^2). BMI categories were classified as underweight (BMI <18.50 kg/m^2), normal (BMI 18.50–24.99 kg/m^2), overweight (BMI 25–29.99 kg/m^2), and obese (BMI >30 kg/m^2) [15]. Calf circumference was recorded with feet flat on the floor and knees and ankles at approximately 90°. We measured the widest part of the uncovered right calf, held the tape gently to avoid compressing the skin, and recorded it to the nearest 0.1 cm [16]. Values equal to or greater than 31 cm were considered well-nourished, and values less than 31 cm were considered malnourished [17]. Information on health status was required, and biochemical parameters from the previous three months were collected from their files. The serum albumin concentration, total cholesterol, total protein, vitamin B12, intrinsic factor (if B12 deficiency), complete blood count (CBC), and total lymphocyte count were obtained from the file of each participant.

2.2.2 Charlson Comorbidity Index

Health researchers widely use this mortality prediction tool to assess disease burden and case mix based on 17 comorbid conditions and their severity [18]. The comorbidities included in the questionnaire were “age, myocardial infarction, congestive heart failure, peripheral vascular disease, cerebrovascular accident or transient ischemic attack, dementia, chronic obstructive pulmonary disease, connective tissue disease, peptic ulcer disease, liver disease, diabetes mellitus (DM), hemiplegia, moderate to severe chronic kidney disease, solid tumor, leukemia, lymphoma and acquired immunodeficiency syndrome”. To estimate disease burden, we assigned weighted scores to each comorbid condition to reflect severity, based on comparative 1-year mortality risk [18].

2.2.3 Medication History

Medical history data obtained included DM and its duration (years), use of any regulated DM medications, duration of metformin use (in years), daily metformin (mg) dose, other oral hypoglycemic agent used, use of proton pump inhibitors (PPIs; Nexium or Losec), duration of PPI use, polypharmacy, use of any supplements, multivitamin use, B12 oral supplements for more than three months, B12 supplement injections for more than three months, and duration of intake (in months).

2.2.4 Evaluation of Nutritional Status

The MNA, used in this study, is a practical assessment tool for screening and categorizing the nutritional status of older patients [19,20], which detects the risk of malnutrition before a significant change in weight or serum proteins. The MNA, administered by a trained researcher, includes 18 questions and takes about 15 minutes to complete. It includes a general assessment of dietary status (number and type of meals) and health (medications, lifestyle, and mobility), a patient self-assessment, and anthropometric measurements. The total score obtained at the end of the test was used to classify the nutritional status of the patient as normal, at risk of malnutrition, or malnourished [20]. According to these results, scores were categorized as 24 or more (normal), 17–23 (risk of malnutrition), and less than 17 (malnutrition) [20].

2.2.5 Serum Cobalamin

Serum cobalamin is the most commonly used test and is considered the initial investigation for vitamin B12 deficiency. The reference value indicating vitamin B12 deficiency was <148 pmol/L; a value between 148–221 pmol/L was considered borderline deficiency, and a value >221 pmol/L was considered normal [21].

2.3 Statistical Analysis

After collection, data were reviewed, coded, and entered into IBM SPSS version 22.0 (IBM Corp., Armonk, NY, USA). Descriptive analyses based on frequency and percentage distributions were conducted for all variables, including demographic data, nutritional status, medical history, drug history, and anthropometric measures. Cross-tabulations (complex tables) were used to assess the distribution of nutritional status and to identify determinants of vitamin B12 deficiency in older adults. Associations between categorical variables were assessed using the Pear-

son chi-square test on cross-tabulations, while the exact probability test was used for small frequency distributions. Firth-penalized binary logistic regression was used to explore associations between study variables and nutritional and vitamin B12 status. This method provided more reliable estimates given the relatively small number of outcome events and the possibility of sparse data or separation [22]. Variables included in the multivariable model were selected based on previous studies and published evidence regarding factors associated with nutritional status; adjusted odds ratios (AORs) with 95% confidence intervals (CIs) were used to present the results. Participants with missing total protein measurements were excluded from analyses involving total protein. No imputation was performed. A p-value < 0.05 was considered statistically significant.

3. Results

3.1 Demographic Data and Nutritional Status of Older Adults

Table 1 presents demographic variables and their relationship to nutritional status among older participants in an outpatient geriatric clinic. Of the participants, 14.2% were malnourished, 62.5% were at risk for malnutrition, and 23.3% were normal. The results indicate that 52.5% of participants were female, 75.8% were illiterate, 59.2% were unemployed, and 94.2% lived with family or friends. Most participants were non-smokers (96.7%). Malnutrition was observed in 40% of older individuals aged 80 years or older, compared with 6.5% among those younger than 70 years, showing a statistically significant association between age and nutritional status (p = 0.001). Older age groups showed higher malnutrition prevalence and lower rates of normal nutritional status. Similarly, a statistically significant association was noted between marital status and nutritional status (p = 0.020), with divorced or widowed individuals showing higher rates of malnutrition and lower rates of normal nutritional status compared with married individuals (p = 0.020). Monthly income and nutritional status (p = 0.001) and educational level and nutritional status (p = 0.018) were significantly associated. The highest number of malnourished participants was reported in the low-income category and among the illiterate group. Malnutrition was not evenly distributed across monthly income and education categories. Therefore, these results should be interpreted cautiously, as some groups had very small sample sizes. However, all other demographic data (occupation, gender, smoking, and BMI) showed no significant association with the nutritional status of participants.

3.2 Distribution of Hematological and Biochemical Parameters in Older Adults by Nutritional Status

Table 2 presents the distribution of hematological and biochemical (blood analysis) parameters by nutritional status among older participants. Hemoglobin levels below 140 g/L were observed in 58.8% of malnourished older adults, compared with 32.1% of those with normal nutritional status (p = 0.009). Although hypoalbuminemia (<35) was more common in malnourished older adults than in those with normal nutritional status (41.2% vs. 7.1%), many malnourished older adults had albumin values within the normal range (p = 0.014). Therefore, a normal serum albumin level alone should be interpreted with caution, as it has limited value as a standalone indicator or diagnostic marker of malnutrition.

3.3 Medical and Medication History

Table 3 presents the medical and medication histories of the participants. The study found that 60.8% of participants had diabetes, 12.5% were prediabetic, 79.5% had lived with DM for more than five years, and 87.5% were receiving treatment. A total of 78.4% of participants reported taking metformin for more than two years, 23.3% were using PPIs, and 48.3% of older adults had polypharmacy (≥5 drugs). Among older adults, 42.5% took multivitamins, 40% used oral vitamin B12 supplements for three months, and 15% received vitamin B12 injections. A Charlson comorbidity index of 6–9 was observed in 12.5% of older adults.

3.4 Distribution of Older Adult Comorbidity and Anthropometric Measures by Nutritional Status

Table 4 presents the distribution of comorbidity and anthropometric measures by nutritional status among older adults. Results indicate that 64.7% of malnourished older adults had polypharmacy of ≥5 drugs, compared with 21.4% of those with normal nutritional status, showing a statistically significant association between polypharmacy and nutritional status (p = 0.001). Participants with polypharmacy of ≥5 drugs had a higher prevalence of malnutrition (p = 0.001). Calf circumference of less than 31 cm was observed in 76.5% of malnourished older adults, compared with 33.3% of those at risk of malnutrition and 7.1% of those with normal nutrition (p = 0.001). We observed that 52.9% of the malnourished group had lost more than 3 kg in the past 3 months, compared with 28% of those at risk of malnutrition and none among participants with normal nutritional status (p = 0.001). Moreover, 52.9% of malnourished older adults reported severe loss of appetite in the past 3 months, compared with 32% of those at risk and none with normal nutritional status (p = 0.001). This study found no significant association between PPI use or CCI and nutritional status.

3.5 Multivariate Analysis of Nutritional Status

Nutritional status was analyzed as a binary outcome, with participants classified as either having normal nutritional status or being at risk of malnutrition/malnourished. Among the 120 participants, 28 (23.3%) had normal nutritional status, whereas 92 (76.7%) were classified as at risk of malnutrition or malnourished. A Firth-penalized binary

Table 1. Biodemographic characteristics of older individuals in the outpatient geriatric clinic, Riyadh, Saudi Arabia.

Biodemographic data	Nutritional status			Total	*p*-value
	Malnutrition (n = 17)	At risk of malnutrition (n = 75)	Normal (n = 28)		
	n (%)	n (%)	n (%)	n (%)	
Age (years)					0.001*
60–70	3 (6.5)	27 (58.7)	16 (34.8)	46 (38.4)	
71–80	4 (8.2)	36 (73.5)	9 (18.4)	49 (40.8)	
81–90	10 (40.0)	12 (48.0)	3 (12.0)	25 (20.8)	
Gender					0.272
Male	7 (12.3)	33 (57.9)	17 (29.8)	57 (47.5)	
Female	10 (15.9)	42 (66.7)	11 (17.5)	63 (52.5)	
Marital status					0.020*
Married	8 (11.2)	41 (56.9)	23 (31.9)	72 (60.0)	
Divorced/widowed	9 (18.8)	34 (70.8)	5 (10.4)	48 (40.0)	
Monthly income (SAR, 1 USD = 3.75 SAR)					0.001*
<3000	14 (13.6)	72 (69.9)	17 (16.5)	103 (85.8)	
3000–6000	1 (11.1)	2 (22.2)	6 (66.7)	9 (7.5)	
7000–9000	2 (50.0)	1 (25.0)	1 (25.0)	4 (3.3)	
>9000	0 (0.0)	0 (0.0)	4 (100.0)	4 (3.3)	
Educational years					0.018*
Illiterate	15 (16.5)	62 (68.1)	14 (15.4)	91 (75.8)	
<4 years of study	1 (9.1)	4 (36.4)	6 (54.5)	11 (9.2)	
>4 years of study	0 (0.0)	7 (53.8)	6 (46.2)	13 (10.8)	
Graduate	1 (20.0)	2 (40.0)	2 (40.0)	5 (4.2)	
Occupation					0.209
Unemployed	11 (15.5)	48 (67.6)	12 (16.9)	71 (59.2)	
Retired	6 (12.8)	25 (53.2)	16 (34.0)	47 (39.2)	
Working	0 (0.0)	2 (100.0)	0 (0.0)	2 (1.7)	
Residential status					0.305
Alone	1 (14.3)	6 (85.7)	0 (0.0)	7 (5.8)	
Family/friends	16 (14.2)	69 (61.1)	28 (24.7)	113 (94.2)	
Smoking					0.320
Non-smoker	16 (13.8)	74 (63.8)	26 (22.4)	116 (96.7)	
Ex-smoker	0 (0.0)	1 (50.0)	1 (50.0)	2 (1.7)	
Current smoker	1 (50.0)	0 (0.0)	1 (50.0)	2 (1.7)	
BMI (kg/m^2) (mean ± SD)	26.41 ± 5.62	31.59 ± 7.51	31.50 ± 6.53	30.83 ± 7.23	0.131
Normal	8 (29.6)	15 (55.6)	4 (14.8)	27 (22.5)	
Overweight	6 (15.0)	24 (60.0)	10 (25.0)	40 (33.3)	
Obese	3 (5.7)	36 (67.9)	14 (26.4)	53 (44.2)	

Values are presented as numbers (%); test used: exact probability test; **p*-value < 0.05 is significant; n = 120; relation is complex (table, cross-tabulation); normal (18.50–24.99 kg/m^2), overweight (25–29.99 kg/m^2), and obese (>30 kg/m^2). SAR, Saudi Riyal; BMI, body mass index; SD, standard deviation.

logistic regression model was used to examine factors associated with nutritional status (Table 5). The model included age, education level, gender, and marital status as explanatory variables. The reference categories were 60–70 years for age, illiterate for education, male for gender, and married for marital status. Age was not significantly associated with nutritional status. Compared with participants aged 60–70 years, those aged 71–80 years had an AOR of 1.14 (95% CI: 0.39–3.35; $p = 0.812$) for being at risk of malnutrition or malnourished, while those aged >80 years had an AOR of 1.42 (95% CI: 0.33–6.14; $p = 0.635$). Education level was significantly associated with nutritional status. Compared with illiterate participants, those with <4 years of education had lower odds of being at risk of malnutrition or malnourished (AOR = 0.22, 95% CI: 0.05–0.97; $p = 0.046$). Similarly, participants with ≥4 years of education had lower odds of being at risk of malnutrition or malnourished compared with those who were illiterate (AOR =

Table 2. Distribution of hematological and biochemical (blood analysis) parameters among older adults by nutritional status.

Laboratory investigations	Nutritional status			Total	*p*-value
	Malnutrition	At risk of - malnutrition	Normal		
	n (%)	n (%)	n (%)	n (%)	
Vitamin B12 (pmol/L)					0.573
Deficient	2 (11.8)	13 (17.3)	3 (10.7)	18 (15.0)	
Borderline	1 (5.9)	13 (17.3)	6 (21.4)	20 (16.7)	
Normal	14 (82.3)	49 (65.4)	19 (67.9)	82 (68.3)	
Serum albumin (g/L)					0.014*
<35	7 (41.2)	25 (33.3)	2 (7.1)	34 (28.3)	
35–50	10 (58.8)	50 (66.7)	26 (92.9)	86 (71.7)	
Total cholesterol (mmol/L)					0.772
Normal	13 (76.5)	57 (76.0)	23 (82.1)	93 (77.5)	
Borderline	4 (23.5)	17 (22.7)	4 (14.3)	25 (20.8)	
High	0 (0.0)	1 (1.3)	1 (3.6)	2 (1.7)	
Total protein (g/L) [#]					0.363
Missing total protein data	3 (17.6)	2 (2.7)	14 (50.0)	19 (15.8)	
<60	3 (17.6)	8 (10.7)	3 (10.7)	14 (11.7)	
60–83	10 (58.9)	64 (85.3)	11 (39.3)	85 (70.8)	
>83	1 (5.9)	1 (1.3)	0 (0.0)	2 (1.7)	
Red blood cell (RBC) count					0.094
$<4.0 \times 10^{12}$/L	10 (58.8)	43 (57.3)	8 (28.6)	61 (50.8)	
$4.0–6.2 \times 10^{12}$/L	6 (35.3)	30 (40.0)	19 (67.9)	55 (45.8)	
$>6.2 \times 10^{12}$/L	1 (5.9)	2 (2.7)	1 (3.6)	4 (3.3)	
Hemoglobin concentration (g/L) [##]					0.009*
≤140	10 (58.8)	42 (56.0)	9 (32.1)	61 (50.8)	
141–160	7 (41.2)	33 (44.0)	18 (64.3)	58 (48.4)	
161–180	0 (0.0)	0 (0.0)	1 (3.6)	1 (0.8)	
White blood cell (WBC)					0.859
$<4 \times 10^9$/L	3 (17.6)	8 (10.7)	2 (7.1)	13 (10.8)	
$4–11 \times 10^9$/L	13 (76.5)	63 (84.0)	24 (85.8)	100 (83.4)	
$>11 \times 10^9$/L	1 (5.9)	4 (5.3)	2 (7.1)	7 (5.8)	
Platelet count					0.828
$<150 \times 10^9$/L	2 (11.8)	8 (10.7)	1 (3.6)	11 (9.2)	
$150–400 \times 10^9$/L	13 (76.4)	58 (77.3)	24 (85.7)	95 (79.2)	
$>400 \times 10^9$/L	2 (11.8)	9 (12.0)	3 (10.7)	14 (11.6)	
Total lymphocyte count (TLC) -					0.709
$<1.5 \times 10^9$/L -	3 (17.6)	8 (10.7)	3 (10.7)	14 (11.7)	
$\geq 1.5 \times 10^9$/L	14 (82.4)	67 (89.3)	25 (89.3)	106 (88.3)	

Values are presented as numbers (%); test used: Exact probability test; **p*-value < 0.05 is significant; n = 120; the relationship is shown in the complex table (cross-tabulation); [#]missing data are reported for transparency to indicate the extent of missing data. Analyses involving total protein were performed after excluding participants with missing total protein data; no imputation was performed. [##] Hemoglobin was included as a laboratory parameter, and the categories used were intended for descriptive purposes only, not for anemia classification. TLC, total lymphocyte count; 1×10^9/L = 1000 cells/mm^3 (so 1.5×10^9/L = 1500 cells/mm^3).

0.25, 95% CI: 0.07–0.85; $p = 0.026$). Gender was not significantly associated with nutritional status. Females had an AOR of 0.89 (95% CI: 0.31–2.55; $p = 0.824$) compared with males, indicating no statistically significant difference between the two groups. Marital status showed a significant association for widowed participants. Compared with married participants, widowed participants had higher odds of being at risk of malnutrition or malnourished (AOR = 4.12, 95% CI: 1.10–15.47; $p = 0.036$). No statistically significant association was observed between divorce and marital status (AOR = 0.43, 95% CI: 0.06–2.97; $p = 0.391$). Overall, the analysis indicated that educational attainment and marital status were associated with nutritional status. Participants with higher levels of education had lower odds of being at risk of malnutrition or malnourished. In contrast, widowed participants had higher odds of being at risk of

Table 3. Medical and medication history of the older adults in the outpatient geriatric clinic, Riyadh, Saudi Arabia.

Medical and medication history	n (%)	Medical and medication history	n (%)
Diabetes mellitus		Polypharmacy	
Normal	32 (26.7)	None	27 (22.5)
Prediabetic	15 (12.5)	<5	35 (29.2)
Diabetic	73 (60.8)	≥5	58 (48.3)
Duration of diabetes mellitus (years)		Use any supplements	
<1	9 (10.2)	Yes	58 (48.3)
1–5	9 (10.2)	No	62 (51.7)
>5	70 (79.5)	Type of supplements	
Regulated diabetes mellitus medications		Oral	57 (98.3)
Yes	77 (87.5)	Injection	1 (1.7)
No	11 (12.5)	Multivitamin use	
Duration of metformin use (years)		Yes	51 (42.5)
Not used	11 (12.5)	No	69 (57.5)
<2	8 (9.1)	B12 supplements oral/3 month	
>2	69 (78.4)	Yes	48 (40.0)
Daily dose of metformin (mg)		No	72 (60.0)
500	65 (84.4)	Dose of vitamin B12	
750	5 (6.5)	1000 mcg	2 (4.2)
1000	5 (6.5)	500 mcg	43 (89.6)
1500	2 (2.6)	B complex (200 mcg)	3 (6.3)
Oral hypoglycemic agents used other than metformin		B12 supplement injections/3 month	
None	41 (46.6)	Yes	18 (15.0)
Glitazones	6 (6.8)	No	102 (85.0)
Insulin	41 (46.6)	Duration of B12 supplement injections	
Proton pump inhibitors		1–3	9 (50.0)
Yes	28 (23.3)	>3	9 (50.0)
No	92 (76.7)	Charlson comorbidity index (CCI)	
Duration of proton pump inhibitor use		2–5	105 (87.5)
0–2	6 (21.4)	6–9	15 (12.5)
3–5	1 (3.6)		
>5	21 (75.0)		

Results are presented as frequency (percentage) for categorical variables.

malnutrition or malnourished compared with married participants.

3.6 Determinants of Vitamin B12 Deficiency Among Older Adults in the Outpatient Geriatric Clinic, Riyadh, Saudi Arabia

Table 6 shows the association between participant characteristics and serum vitamin B12 levels. The results show that 26.7% of older participants with prediabetes and 19.2% with DM had vitamin B12 deficiency, compared with none among older participants with normal levels (p = 0.008). Although diabetes was associated with serum vitamin B12 levels, metformin was not, so interpret this finding with caution. All other variables were not significantly associated ($p > 0.05$). Table 6 also presents the distribution of PPI use and nutritional status by vitamin B12 level among older adults. The results show no significant association between vitamin B12 status and PPI use, duration of use, or nutritional status ($p > 0.05$).

3.7 Multivariate Analysis of Vitamin B12 Status

Vitamin B12 status was analyzed as a binary outcome, with participants classified as having either normal or borderline/deficient vitamin B12 status (Table 7). Among the 120 participants, 82 (68.3%) had normal vitamin B12 status, while 38 (31.7%) had borderline or deficient vitamin B12 status. A Firth-penalized binary logistic regression model (Table 7) was fitted to examine factors associated with vitamin B12 status. The model included age, DM, nutritional status, PPI use, oral vitamin B12 supplementation, and injectable vitamin B12 supplementation. Age was not significantly associated with borderline/deficient vitamin B12 status. Compared with participants aged 60–70 years, the AOR was 1.18 (95% CI: 0.50–2.78; p = 0.186) for those aged 71–80 years and 0.48 (95% CI: 0.14–1.48; p = 0.100) for those aged >80 years. DM was not significantly associated with borderline/deficient vitamin B12 status. Compared with participants with diabetes, those with normal glucose status or prediabetes had an AOR of 0.67

Table 4. Distribution of comorbidities and anthropometric measures among older adults by nutritional status.

Items	Nutritional status			Total	*p*-value
	Malnutrition	At risk of - malnutrition	Normal		
	n (%)	n (%)	n (%)	n (%)	
Charlson comorbidity index					0.250
2–5	14 (82.4)	64 (85.3)	27 (96.4)	105 (87.5)	
6–9	3 (17.6)	11 (14.7)	1 (3.6)	15 (12.5)	
Proton pump inhibitors					0.087
Yes	1 (5.9)	22 (29.3)	5 (17.9)	28 (23.3)	
No	16 (94.1)	53 (70.7)	23 (82.1)	92 (76.7)	
Polypharmacy					0.001*
None	1 (5.9)	22 (29.3)	4 (14.3)	27 (22.5)	
<5	5 (29.4)	12 (16.0)	18 (64.3)	35 (29.2)	
≥5	11 (64.7)	41 (54.7)	6 (21.4)	58 (48.3)	
Calf circumference (cm)					0.001*
<31	13 (76.5)	25 (33.3)	2 (7.1)	40 (33.3)	
≥31	4 (23.5)	50 (66.7)	26 (92.9)	80 (66.7)	
Weight loss over the last 3 months					0.001*
None	3 (17.6)	18 (24.0)	26 (92.9)	47 (39.2)	
1–3 kg	5 (29.5)	36 (48.0)	2 (7.1)	43 (35.8)	
>3 kg	9 (52.9)	21 (28.0)	0 (0.0)	30 (25.0)	
Loss of appetite over the last 3 months					0.001*
No loss	0 (0.0)	17 (22.7)	26 (92.9)	43 (35.8)	
Moderate loss	8 (47.1)	34 (45.3)	2 (7.1)	44 (36.7)	
Severe loss	9 (52.9)	24 (32.0)	0 (0.0)	33 (27.5)	

Values are presented as numbers (%); test used: Exact probability test; *p-value < 0.05 is significant; n = 120; relationship is complex (table, cross-tabulation).

Table 5. Firth-Penalized binary logistic regression analysis of factors associated with nutritional status.

Predictor	Comparison	AOR	95% CI	*p*-value
Age	71–80 vs. 60–70 years	1.14	0.39–3.35	0.812
	>80 vs. 60–70 years	1.42	0.33–6.14	0.635
Education	<4 years vs. illiterate	0.22	0.05–0.97	0.046*
	≥4 years vs. illiterate	0.25	0.07–0.85	0.026*
Gender	Female vs. male	0.89	0.31–2.55	0.824
Marital status	Widowed vs. married	4.12	1.10–15.47	0.036*
	Divorced vs. married	0.43	0.06–2.97	0.391

Note: AOR, adjusted odds ratio; CI, confidence interval. The model was adjusted for age, education level, gender, and marital status. The outcome was coded as normal versus at-risk or malnourished. Reference categories were 60–70 years for age, illiterate for education, male for gender, and married for marital status. Firth-Penalized binary logistic regression was used. *p-value < 0.05 is significant.

(95% CI: 0.30–1.47; $p = 0.096$). Nutritional status was also not significantly associated with borderline/deficient vitamin B12 status. Participants classified as at risk of malnutrition or malnourished had an AOR of 1.03 (95% CI: 0.42–2.66; $p = 0.226$) compared with those with normal nutritional status. Similarly, no statistically significant associations were observed for PPI use (AOR = 0.67, 95% CI: 0.24–1.75; $p = 0.155$), oral vitamin B12 supplementation (AOR = 1.04, 95% CI: 0.37–2.78; $p = 0.254$), or injectable vitamin B12 supplementation (AOR = 1.83, 95% CI: 0.55–6.18; $p = 0.170$). Overall, none of the variables in the final Firth-penalized binary logistic regression model showed a statistically significant association with borderline/deficient vitamin B12 status.

4. Discussion

This study emphasizes the importance of assessing malnutrition and malnutrition risk, as both increase mor-

Table 6. Determinants of vitamin B12 deficiency among older adults in the outpatient geriatric clinic, Riyadh, Saudi Arabia.

Variables	Vitamin B12			Total	*p*-value
	Deficient (<148 pmol/L) n = 18	Borderline (148–221 pmol/L) n = 20	Normal (>221 pmol/L) n = 82		
	n (%)	n (%)	n (%)	n (%)	
Age (years)					0.283
60–70	5 (10.9)	10 (21.7)	31 (67.4)	46 (38.4)	
71–80	11 (22.4)	7 (14.3)	31 (63.3)	49 (40.8)	
81–90	2 (8.0)	3 (12.0)	20 (80.0)	25 (20.8)	
Gender					0.139
Male	6 (10.5)	7 (12.3)	44 (77.2)	57 (47.5)	
Female	12 (19.0)	13 (20.6)	38 (60.3)	63 (52.5)	
Educational years					0.412
Illiterate	17 (18.7)	13 (14.3)	61 (67.0)	91 (75.8)	
<4 years of study	0 (0.0)	2 (18.2)	9 (81.8)	11 (9.2)	
>4 years of study	1 (7.7)	4 (30.8)	8 (61.5)	13 (10.8)	
Bachelor graduate	0 (0.0)	1 (20.0)	4 (80.0)	5 (4.2)	
Occupation					0.917
Unemployed	11 (15.5)	12 (16.9)	48 (67.6)	71 (59.1)	
Retired	7 (14.9)	8 (17.0)	32 (68.1)	47 (39.2)	
Working	0 (0.0)	0 (0.0)	2 (100.0)	2 (1.7)	
Residential status					0.480
Alone	0 (0.0)	1 (14.3)	6 (85.7)	7 (5.8)	
Family/friends	18 (15.9)	19 (16.8)	76 (67.3)	113 (94.2)	
Smoking					0.751
Non-smoker	18 (15.5)	20 (17.2)	78 (67.2)	116 (96.6)	
Ex-smoker	0 (0.0)	0 (0.0)	2 (100.0)	2 (1.7)	
Current smoker	0 (0.0)	0 (0.0)	2 (100.0)	2 (1.7)	
Diabetes mellitus					0.008*
Normal	0 (0.0)	9 (28.1)	23 (71.9)	32 (26.7)	
Prediabetic	4 (26.7)	4 (26.7)	7 (46.7)	15 (12.5)	
Diabetic	14 (19.2)	7 (9.6)	52 (71.2)	73 (60.8)	
Duration of diabetes mellitus (years)					0.822
<1	2 (22.2)	0 (0.0)	7 (77.8)	9 (10.2)	
1–5	2 (22.2)	1 (11.1)	6 (66.7)	9 (10.2)	
>5	14 (20.0)	10 (14.3)	46 (65.7)	70 (79.6)	
Duration of metformin (years)					0.850
Not used	1 (9.1)	1 (9.1)	9 (81.8)	11 (12.5)	
<2	2 (25.0)	1 (12.5)	5 (62.5)	8 (9.1)	
>2	15 (21.7)	9 (13.0)	45 (65.2)	69 (78.4)	
A daily dose of metformin (mg)					0.408
500	12 (18.5)	9 (13.8)	44 (67.7)	65 (84.4)	
750	1 (20.0)	1 (20.0)	3 (60.0)	5 (6.5)	
1000	3 (60.0)	0 (0.0)	2 (40.0)	5 (6.5)	
1500	1 (50.0)	0 (0.0)	1 (50.0)	2 (2.6)	
Proton pump inhibitors					
Use of proton pump inhibitors					0.910
Yes	4 (22.2)	4 (20.0)	20 (24.4)	28 (23.3)	
No	14 (77.8)	16 (80.0)	62 (75.6)	92 (76.7)	
Duration of use					0.483
0–2	0 (0.0)	2 (50.0)	4 (20.0)	6 (21.4)	
3–5	0 (0.0)	0 (0.0)	1 (5.0)	1 (3.6)	
>5	4 (100.0)	2 (50.0)	15 (75.0)	21 (75.0)	

Table 6. Continued.

Variables	Vitamin B12			Total	*p*-value
	Deficient (<148 pmol/L) n = 18	Borderline (148–221 pmol/L) n = 20	Normal (>221 pmol/L) n = 82		
	n (%)	n (%)	n (%)	n (%)	
Protein intake during the last 3 months					0.510
Light	0 (0.0)	2 (10.0)	9 (11.0)	11 (9.2)	
Moderate	4 (22.2)	2 (10.0)	10 (12.2)	16 (13.3)	
Good	14 (77.8)	16 (80.0)	63 (76.8)	93 (77.5)	
Nutritional status					0.573
Malnutrition	2 (11.8)	1 (5.9)	14 (82.4)	17 (14.2)	
At risk of malnutrition	13 (17.3)	13 (17.3)	49 (65.3)	75 (62.5)	
Normal	3 (10.7)	6 (21.4)	19 (67.9)	28 (23.3)	

Values are presented as numbers (%); test used: Exact probability test; *p-value < 0.05 is significant; n = 120; relation is complex (table, cross-tabulation).

Table 7. Firth-penalized binary logistic regression analysis of factors associated with vitamin B12 status.

Predictor	Comparison	AOR	95% CI	*p*-value
Age	71–80 vs. 60–70 years	1.18	0.50–2.78	0.186
	>80 vs. 60–70 years	0.48	0.14–1.48	0.100
Diabetes mellitus	Normal/prediabetes vs. diabetes	0.67	0.30–1.47	0.096
Nutritional status	At risk + malnourished vs. normal	1.03	0.42–2.66	0.226
Proton pump inhibitors	Yes vs. no	0.67	0.24–1.75	0.155
Oral B12 supplementation	Yes vs. no	1.04	0.37–2.78	0.254
Injectable B12 supplementation	Yes vs. no	1.83	0.55–6.18	0.170

Note: The model was adjusted for age, diabetes mellitus, nutritional status, proton pump inhibitor use, oral vitamin B12 supplementation, and injectable vitamin B12 supplementation. The outcome was coded as normal (>221 pmol/L) versus borderline or deficient (≤221 pmol/L). Reference categories were 60–70 years for age, diabetes for diabetes mellitus, normal for nutritional status, no for proton pump inhibitor use, no for oral vitamin B12 supplementation, and no for injectable vitamin B12 supplementation. Firth-penalized binary logistic regression was used.

bidity and mortality. A study of 209 geriatric outpatients found that malnutrition was a significant factor in mortality risk over a follow-up period of 6 months to 7 years [23]. Based on the MNA evaluation, the present study observed that 76.7% of older participants aged 60 years and older were either malnourished or at risk of malnutrition. Malnutrition remains a significant challenge among older adults in Saudi Arabia, where many geriatric patients are either malnourished or at high risk. Our findings align with local studies on malnutrition prevalence among older individuals. In geriatric outpatient clinics in Tabuk [24], using the mini-nutritional assessment tool (MNA-SF), and in Jeddah [25], using MNA, malnutrition prevalence was 17.3% and 5.3%, respectively. In comparison, 41.4% and 32.9% were at risk of malnutrition, respectively. Another study in the Makkah region reported that 67.2% of older adults were malnourished or at risk of malnutrition [26]. Malnutrition was also observed in regional Gulf countries. Déchelotte et al. [27], in an observational cross-sectional study at a hospital in Beirut, reported that 52% were at risk of malnutrition and 13.5% were malnourished. Another cross-sectional study in long-term care facilities in Qatar reported that 85% of participants were malnourished [28], which is higher than the prevalence reported in this study.

Globally, comparable prevalence rates have been observed among older adults receiving geriatric care. In an international study of 360 older adults in India, 15% were malnourished, and 55% were at risk of malnutrition [29]. In another study by Cin et al. [6] on 215 older patients in a geriatric outpatient clinic in Turkey, the prevalence of malnutrition and risk of malnutrition based on MNA was 3.2% and 24.7%, respectively. Although our findings align with some previous research, we observed discrepancies with others despite similar assessment criteria and the use of nearly the same tool to evaluate nutritional status. Based on 196 studies from 22 countries, a systematic review and meta-analysis published in 2019 reported differences in prevalence due to health care settings and screening tools among older adults in Europe [30]. These discrepancies may also reflect differences in sample size, sociodemographic factors, and methodological approaches.

In this study, bivariate analysis showed that several sociodemographic variables, including older age, divorce or widowhood, lower education, and lower monthly income, were associated with poor nutritional status, highlighting the negative influence of social circumstances and limited financial resources on nutrition. Malnutrition was detected in 40% of individuals aged 80 years or older, compared with only 6.5% among those younger than 70 years. These findings align with previous studies showing that age [25,29,31], education level, marital status [31,32], and low household income [31,33] are correlated with nutritional status in older adults. Malnutrition is a multidimensional concept that includes physical and psychological components. Malnutrition can be triggered by loss, dependency, loneliness, and chronic illness and may affect morbidity, mortality, and quality of life [34]. According to the MNA score, older people classified as malnourished had the lowest albumin levels. Low albumin levels in hospitalized older patients have been associated with longer hospital stays and an increased risk of re-admission within 1 year of leaving the hospital [35]. Low serum albumin levels in older adults are a risk factor for all-cause mortality, especially among those with hypoalbuminemia ($\leq$3.5 g/dL) [36]. Bivariate analysis showed that low albumin was significantly associated with malnutrition and risk of malnutrition; however, this association should be interpreted with caution, as albumin has limited value as a standalone indicator or diagnostic marker of malnutrition. Recent studies suggest that serum albumin should complement a comprehensive nutritional assessment rather than serve as an independent diagnostic marker of malnutrition, as it is influenced by inflammation and other nonnutritional factors [37,38]. Fanelli et al. [39] reported that patients with lower protein intake consumed less vitamin B12 and had a higher mean number of functional limitations. In Firth-penalized binary logistic regression, illiterate and widowed older adults had higher odds of being at risk of malnutrition or malnourished compared with their respective reference groups. According to a systematic review that included cross-sectional and observational studies in the meta-analysis of malnutrition and its risk [40], low educational level (odds ratio (OR): 1.48; 95% CI: 1.33–1.64; $p < 0.001$) and being single, widowed, or divorced (OR: 1.73; 95% CI: 1.57–1.90; $p < 0.001$) were linked to malnutrition and its risk. Illiteracy and low education likely indicate poor nutrition literacy, because the inability to read and understand dietary and health-related information may limit the selection, purchase, and preparation of nutritionally adequate meals, which may reduce dietary quality and increase vulnerability to malnutrition [41]. Meanwhile, widowhood is linked to poorer appetite and dietary intake, such as skipping meals and eating a less varied diet, partly due to emotional distress and the loss of shared mealtimes after the death of a spouse [42,43].

In our study, we used calf circumference and BMI as simple, noninvasive measures of malnutrition. Bivariate analysis showed that lower calf circumference was associated with malnutrition, consistent with previous studies [44,45]. None of the participants were underweight by BMI; however, the MNA identified participants with malnutrition, highlighting that BMI alone cannot determine nutritional status. Low BMI is often considered a phenotypic indicator of malnutrition, but obesity can also mask true malnutrition; people diagnosed with obesity can experience loss of skeletal muscle mass and function, which has a serious impact on morbidity and survival [46]. Medications play a vital role in influencing the nutritional status of older adults. A recent systematic review identified seven cross-sectional studies (2000–2020) that consistently reported an association between polypharmacy (use of $\geq$5 medications daily) and an increased risk of malnutrition or its onset in older adults [47]. We observed that older people on polypharmacy were more malnourished than those who were not on polypharmacy, which may be explained by the possibility that the older individuals taking medications had underlying health conditions that were themselves a consequence of malnutrition [48]. We did not examine the underlying mechanisms in this study; however, previous research shows that older people take at least one medicine [49] and that, because of medication side effects, adults over 65 often experience decreased saliva production, which can make eating difficult [50]. Some medicines also alter taste and smell or cause nausea and may reduce appetite [51].

Alzahrani et al. [25] reported that malnourished older adults had a higher rate of weight loss, primarily attributed to factors such as loss of appetite. Poor dietary intake in older adults often stems from a combination of physiological and pathological factors [48], and malnutrition can worsen rapidly during acute illnesses due to increased catabolism of lean body tissue [52]. We observed that although polypharmacy was associated with malnutrition in our study, CCI was not. This discrepancy may reflect that polypharmacy captures the pharmaceutical burden and may include effects on appetite, drug-nutrient interactions, and gastrointestinal symptoms reported in previous studies [53,54], whereas we did not evaluate these mechanisms in the present study; conversely, CCI reflects the burden of specific chronic conditions. We observed a relatively low comorbidity burden among participants, likely because most had few comorbidities, with 87.5% scoring 2–5 on the Charlson index. These findings contrast with previous studies that found a stronger relationship between nutritional status and comorbidities [55,56]. The regression results in this study should be interpreted with caution because the small number of malnourished older adults may make the model unstable.

Nutritional status in older adults is often compromised by factors such as disability and disease, with borderline vitamin deficiencies commonly resulting from poor dietary

intake and increased nutrient needs due to illness [57]. Since various measurement methods and reference ranges are used to assess vitamin B12 deficiency, no "gold standard" exists. In this study, the prevalence of cobalamin deficiency, defined as a serum cobalamin level <148 pmol/L, was 15% in patients over age 60, while 16.7% of older individuals were in the borderline vitamin B12 zone (149–221 pmol/L). Alshatwi [21], using the same cutoff as in this study, reported low serum vitamin B12 in 5.6% of older adults, while 23.9% had marginal vitamin B12 deficiency. In a recent study, the prevalence of vitamin B12 deficiency was 3.6%, and 66.1% of participants had borderline B12 levels [58]. Previously, low serum vitamin B12 levels have been associated with impaired vitamin B12 absorption, and atrophic gastritis is considered a major cause of impaired vitamin B12 absorption in older adults. Because of atrophic gastritis, the gastric mucosa secretes less acid and pepsin, reducing the amount of free vitamin B12 released from food. Several factors could explain variations in vitamin B12 levels worldwide, including different cutoff levels used in studies, cultural and religious beliefs, and dietary habits [58].

Intracellular vitamin B12 deficiency impairs methylmalonyl-CoA mutase and the methionine synthase pathway, leading to elevated methylmalonic acid (MMA) and homocysteine levels. Therefore, a decrease in serum B12 without an increase in these metabolites may reflect plasma-level declines rather than functional tissue deficiency [59]. Thus, MMA and homocysteine increase the sensitivity of vitamin B12 deficiency detection, but unfortunately these tests were not available at our facility. Bivariate analysis showed that, based on serum cobalamin concentrations, older participants who were prediabetic or had diabetes had higher rates of vitamin B12 deficiency; however, this association was not observed in the Firth-penalized binary logistic regression model. In our study, the difference between unadjusted and adjusted models may reflect the influence of other covariates and a smaller number of participants with vitamin B12 deficiency; therefore, this finding should be interpreted with caution and considered exploratory pending confirmation in larger studies. Unlike this study, other cross-sectional studies [58,60] have shown a higher occurrence of vitamin B12 deficiency among patients with type 2 DM, which has been explained by cytosolic metabolic resistance to vitamin B12 [61]. Long-term metformin use has been reported as a major factor in the association between vitamin B12 deficiency and type 2 diabetes, as it impairs vitamin absorption in the intestinal tract [62,63]. Although the exact mechanism behind the association between metformin use and vitamin B12 deficiency is not clear, metformin is thought to impair calcium-dependent vitamin B12 absorption in the ileum [64] due to the binding of the hydrophobic tail of biguanide to the hydrocarbon core in the cell membrane, leading to the displacement of divalent cations such as calcium [62]. Unlike previous studies, this study found no association between metformin use, PPI use, and duration of use and vitamin B12 deficiency [58,65,66]. Factors such as dietary vitamin B12 intake, vitamin B12 supplementation, duration of supplementation, and diabetes or residual confounding may have contributed to the observed association. In addition to metformin use, genetic and environmental factors may also affect deficiency prevalence across populations [67]. The lack of association between PPI use and vitamin B12 deficiency aligns with Lerman et al. [68], but Kwape et al. [69] reported a significant association. PPIs block the gastric H^+K^+-ATPase enzyme, reducing gastric acid production. This acid is necessary to convert pepsinogen to pepsin, an enzyme that helps release vitamin B12 from food; reduced acid can hinder vitamin B12 release from dietary proteins, thereby decreasing its absorption. This study found no association between vitamin B12 and nutritional status, consistent with Soysal et al. [70] in a sample of 1007 older participants.

Nutritional guidelines recommend routine malnutrition screening for all older adults in healthcare settings, including primary care and geriatric services, so that those who are malnourished or at risk can be assessed and treated appropriately [71]. Our study used the MNA, a commonly used nutritional screening tool for older adults, to identify those who are malnourished or at risk. It is important to note that the MNA differs from the Global Leadership Initiative on Malnutrition (GLIM) framework, which is designed to diagnose malnutrition based on the presence of at least one phenotypic and one etiologic criterion [71]; therefore, the MNA categories used in the present study should be interpreted as nutritional screening/assessment categories and should not be considered equivalent to a formal GLIM-based diagnosis of malnutrition. Malnutrition remains an important concern among older adults in Saudi Arabia. These findings have significant implications for nutritional screening in older adults; screening should focus on body weight and intake, as well as micronutrient risk and medication burden in high-risk older adults. For the prevention or reversal of malnutrition, early identification is essential, as it enables the implementation of necessary therapeutic actions. In Saudi Arabia, this is especially pertinent, as malnutrition is already recognized as a public health issue among older adults, with local evidence supporting the need for awareness programs and early detection in geriatric clinics. In terms of public health policy, these findings support implementing nutrition screening procedures, providing recommendations to dietitians, and implementing comprehensive healthy-aging initiatives to improve the health of older adults in Saudi healthcare.

Limitations

The study has several limitations, including a small sample size drawn from a single hospital, which may in-

troduce selection bias and limit the generalizability of the findings. Therefore, the results should be considered preliminary and interpreted with caution, and future research should include community-based populations or multicenter samples. Excluding participants without serum vitamin B12 measurements may have introduced selection bias, as testing is often requested when there is clinical suspicion of deficiency. Some total protein measurements were unavailable, and missing data were not evenly distributed across nutritional-status groups, which may have affected the related analyses. Firth-penalized logistic regression was used to reduce small-sample bias and improve the stability of estimates; however, the relatively small number of participants in the outcome group may have limited the precision of some estimates, as reflected in the wide CI. Larger studies with adequate numbers in each outcome category are needed to confirm these associations. One methodological limitation is that we obtained laboratory results from hospital records, which did not include details on the analytical methods, assays, or instruments used; therefore, we could not include these methodological details in the manuscript. In addition, we did not consider two important biomarkers of vitamin B12 metabolism, homocysteine and MMA, because they were unavailable in the medical records; therefore, the findings should be interpreted in this context.

5. Conclusions

The findings underscore the importance of early assessment of malnutrition and vitamin B12 deficiency among older adults, and management should be approached pragmatically. All hospitals and geriatric care centers in Saudi Arabia should adopt an interdisciplinary approach and enhance nutritional services; meanwhile, the government should develop and implement effective nutritional policies to improve overall population health.

Availability of Data and Materials

The datasets used and analyzed during the current study are available from the corresponding authors on reasonable request.

Author Contributions

RSHA, LNAH and MAA designed the research study. RSHA and MA performed the research. SA and LNAH contributed to the interpretation of the data. SA drafted the manuscript. SA and LNAH critically reviewed the manuscript for important intellectual content. LNAH arranged the funds. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

The study was conducted in accordance with the guidelines of the Declaration of Helsinki and was approved by the Institutional Review Board (IRB) of King Abdullah International Medical Research Center, the National Guard-Health Affairs, with reference number: RYD-20-419812-60356. Written informed consent was obtained from all individuals before enrolment.

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Conflicts of Interest

The authors declare no conflicts of interest.

Declaration of AI and AI-Assisted Technologies in the Writing Process

During the preparation of this manuscript, the author(s) used AI (ChatGPT, OpenAI, San Francisco, CA, USA) for editing assistance and language improvement, specifically to improve spelling, word choice, readability and clarity. The author(s) reviewed and revised all outputs from these tools and take(s) full responsibility for the final content of the work.

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