

Diet Quality, Malnutrition Risk and Micronutrient (Magnesium and Vitamin D) Profile among COVID-19 Survivors: A Post-Recovery Follow-Up Study

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Abstract Long COVID is characterised by persistent symptoms following recovery from acute SARS-CoV-2 infection such as fatigue and muscle pain. Nutritional factors, including diet quality, malnutrition risk and micronutrient status, may influence post-recovery outcomes, yet evidence of this remains limited. This study examined the associations of diet quality, malnutrition risk, and serum levels of magnesium and vitamin D with persistent fatigue and muscle pain among COVID-19 survivors. A retrospective cohort study was conducted on 103 (51 males, 52 females) adults with a mean age of 55.13 ± 14.45 years, previously hospitalised for COVID-19 in the Ha'il region, Saudi Arabia. Data were collected from hospital records and a single post-recovery follow-up assessment conducted 1–3 years after discharge. Nutritional risk was evaluated using the Malnutrition Screening Tool, while dietary adherence and supplement use were assessed through structured questionnaire. Serum magnesium and vitamin D levels were measured at both admission and follow-up. Comparative analyses between participants with and without persistent fatigue or muscle pain were performed using chi-square and Mann–Whitney U tests. Comorbidities and obesity were prevalent among the entire cohort of participants (68.9% and 55.3%, respectively). Serum magnesium levels were significantly lower among individuals with comorbidities such as diabetes (0.78 ± 0.11 mmol/L vs. 0.84 ± 0.095 mmol/L; $p = 0.008$), whereas vitamin D levels showed no significant group differences. Persistent fatigue and muscle pain were associated with higher malnutrition risk scores ($p = 0.019$) and poorer adherence to recommended dietary intake mainly for cereals and fruits groups ($p < 0.05$). No significant associations were found between post-recovery persistent fatigue or muscle pain and serum vitamin D or magnesium levels. This study shows that malnutrition risk and a suboptimal diet persist long after COVID-19 recovery and are more strongly associated with post-viral fatigue and muscle pain than individual micronutrient deficiencies. Comprehensive nutritional rehabilitation, including dietary counselling and monitoring of key micronutrients, is essential for optimising recovery from long COVID.

Keywords: Long COVID, Malnutrition, Diet quality, Vitamin D, Magnesium, Fatigue, Muscle pain, post-COVID rehabilitation

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1. Introduction

Since the emergence of SARS-CoV-2 in late 2019, acute coronavirus disease (COVID-19) has evolved into a

worldwide pandemic with long-lasting clinical, social and economic consequences. Among those infected, a notable proportion have experienced persistent, fluctuating or newly emerging symptoms beyond the acute phase, collectively termed protracted COVID or post-acute sequelae of SARS-CoV-2 (PASC). These symptoms can

potentially continue for months to years after the infectious phase has passed, regardless of the initial disease severity [1,2]. The prevalence of long COVID fluctuates according to the definition, demographic and duration of follow-up. However, a meta-analysis including Coronavirus Disease 2019 (COVID-19) Condition studies showed that 10%–30% of those who were infected reported at least one persistent symptom 3 to 6 months later, with fatigue, dyspnoea, cognitive complaints, sleep disorders and musculoskeletal symptoms being among the most common [2,3]. Studies have suggested that long-lasting effects of COVID-19 infection are related to a combination of factors, including immune system disorder, disruption of autonomic and endothelial systems, damage to small blood vessels and capillaries, persistence of the virus in the body, dysbiosis and other chronic diseases and lifestyle-related factors [4,5].

Nutrition is a major determinant of immune competence and recovery from infection. In acute and post-acute COVID-19 care, expert committees have emphasised comprehensive nutritional assessment and timely intervention to lower the prevalence malnutrition, sarcopenia and micronutrient deficiencies that may worsen outcomes and delay functional recovery [6,7,8]. Individuals are considered to be at greater risk of malnutrition as a result of factors including reduced dietary intake, anosmia/ageusia, inflammatory catabolism, decreased physical activity and psychosocial stressors. The rate of malnutrition is higher among older adults and those with comorbidities, obesity, diabetes or cardiometabolic disease [7,9]. Screening tools such as the Malnutrition Screening Tool (MST) and Global Leadership Initiative on Malnutrition (GLIM) criteria have been recommended to identify at-risk individuals in hospital and community settings across the COVID-19 pandemic [8].

Nutrition profoundly influences immune function, metabolic resilience and recovery from illness [10]. COVID-19 patients are at increased risk of malnutrition because of the associations of such infection with reduced appetite, systemic inflammation and altered metabolism [11,12]. Malnutrition has been shown to be associated with greater disease severity, longer hospital stays and increased mortality in the context of COVID-19 infection [13]. Even after discharge following treatment for acute COVID-19 infection, malnutrition or poor dietary intake may persist and contribute to fatigue, muscle weakness and delayed rehabilitation [14,15]. The MST has been widely used to assess the risk of this and has revealed a high prevalence of nutritional vulnerability among COVID-19 survivors [8].

Diet quality, which includes the overall appropriateness and balance of macronutrients and micronutrients within normal patterns, has been implicated in both vulnerability to severe COVID-19 and the risk of long-term intractable symptoms. Adherence to healthy dietary patterns (e.g., a Mediterranean-style diet rich in fruits, vegetables, whole grains, legumes, nuts and unsaturated fats) has been reported to be related to a lower risk of severe outcomes and reduced systemic inflammation, whereas poor diet quality is associated with a higher likelihood of hospitalisation and prolonged symptoms [16,17]. However, evidence on diet quality and long COVID specifically

remains limited and diverse, with few studies integrating objective biomarkers of micronutrient status with validated malnutrition screening and longitudinal follow-up.

Magnesium and vitamin D are two micronutrients that are important for both immune and metabolic health and for recovery from COVID-19. Magnesium is a cofactor for more than 300 enzymes, including those relevant to energy metabolism, mitochondrial function, neuromuscular activation, endothelial function and inflammatory signals [18,19]. Magnesium deficiency is prevalent globally and linked to insulin resistance, hypertension, susceptibility to arrhythmia and low-grade inflammation—all of which are comorbidities commonly associated with worse COVID-19 outcomes [20,21]. Importantly, magnesium influences vitamin D metabolism and signalling by facilitating hepatic and renal hydroxylation and modulating the activity of vitamin D receptors; magnesium insufficiency can thus decrease the biological response to vitamin D supplementation [22,23]. Studies on COVID-19 have reported associations between lower serum magnesium and increased disease severity, prolonged hospitalisation or higher mortality, although the causes of this have remained unclear and interventional data are scarce [24,25].

Vitamin D, classically involved in calcium–phosphate homeostasis and musculoskeletal health, exerts immunomodulatory effects through the vitamin D receptor expressed on innate and adaptive immune cells [26]. Decreased vitamin D concentrations are common worldwide and has been shown to be associated with increased risk of respiratory tract infections and adverse COVID-19 outcomes in multiple observational cohorts [27,28,29]. Proposed mechanisms behind these associations include modulation of antimicrobial peptide expression, attenuation of proinflammatory cytokine expression and maintenance of epithelial barrier integrity [26]. While randomised trials on patients with acute COVID-19 have yielded mixed results, some data suggest that correction of deficiency vitamin D sublimation may support recovery in particular populations, especially when integrated into broader nutritional strategies [30,31]. Studies of patients after recovery from the acute phase of COVID-19 infection indicate that vitamin D insufficiency may persist beyond recovery, potentially worsening the health status by interacting with reduced exposure to sunlight, physical inactivity, obesity and ongoing inflammation [32,33]. Nevertheless, there has been limited study involving the profiling of both magnesium and vitamin D in combination in the context of long COVID, or analysis of their relationships to malnutrition risk, body composition, symptom persistence and micronutrient supplementation.

Long COVID is often associated with obesity, diabetes and cardiovascular disease, conditions characterised by chronic inflammation, endothelial dysfunction and differences in established nutritional management approaches [32]. Obesity co-occurs with micronutrient deficiencies and sarcopenic obesity, and it increases the risk of severe acute COVID-19 and may increase susceptibility to a protracted recovery [34,35]. Educational and socioeconomic levels may further shape diet quality, healthcare access and adherence to courses of micronutrient supplementation, contributing to disparities

in post-COVID outcomes [36]. In this context, there is a pressing need for pragmatic, post-recovery studies that characterise diet quality and malnutrition risk alongside objective micronutrient measures and real-world micronutrient supplementation practices in individuals with and without multiple comorbidities.

This work addresses this research gap by focusing on the correlations among diet quality, malnutrition risk and micronutrient profile, focusing on magnesium and vitamin D, among Saudi Arabian adults 1–3 years after the acute infectious phase of COVID-19, stratified by comorbidity status. Building on data obtained during hospitalisation, we longitudinally examined body mass index (BMI), malnutrition risk as assessed by MST, persistence of post-COVID symptoms, changes in physical activity, and the prevalence and type of nutritional supplements and herbal remedies used from the acute phase and throughout follow-up.

The results of this study reveal a clinically significant group of long COVID sufferers marked by a high number of comorbidities. The collected data facilitate study of the links between comorbidities, nutritional vulnerability, and micronutrient status over time. This study identifies correlations between clinical data and levels of magnesium and vitamin D before and after treatment. It provides us with information about abnormalities in nutritional factors that might help classify risk and target interventions in long-COVID care. Knowledge of how diet quality, the risk of malnutrition, and magnesium and vitamin D levels are connected could aid the establishment of rehabilitation plans that involve professionals from multiple different fields, help COVID-19 survivors decide whether or not to take supplements and help the prioritization of patients for consultation with a dietitian, especially in places where resources are limited, and chronic diseases are common.

2. Materials and Methods

Study Design, Setting and Participants

This work involved a retrospective cohort study conducted among COVID-19 survivors in the Ha'il region, Kingdom of Saudi Arabia (KSA). The study cohort comprised 103 patients enrolled from among those hospitalised at King Salman Specialist Hospital between January 2021 and July 2023.

As initial screening, approximately 2,700 electronic medical records were comprehensively screened to identify eligible participants confirmed to have SARS-CoV-2 infection by polymerase chain reaction-based testing. Participants were selected based on specific inclusion criteria (e.g. age, residence and medical history). The following exclusion criteria were also applied: pregnancy, aged under 18, and pre-existing conditions known to severely compromise immune or nutritional status (e.g. cancer, immunodeficiency or renal failure). In terms of the final cohort, a total of 600 eligible patients were invited to participate in this study via a phone call, resulting in 103 participants who consented to participate and for whom complete data as required for the analyses were available.

Data Collection

Data collection was executed at two distinct timepoints, combining historical medical records with prospective, research-specific assessments, allowing analyses of both baseline vulnerability and post-recovery status.

Timepoint 1 included data about hospitalization period about the patients' sociodemographic information, acute condition upon COVID-19 diagnosis, baseline health and disease severity were collected retrospectively from electronic medical records using a clinical data collection sheet.

Timepoint 1 focused on the hospitalisation period. During this stage, data were collected retrospectively from electronic medical records using a clinical data collection sheet. Sociodemographic information gathered included age and gender. Details regarding patients' acute condition at the time of COVID-19 diagnosis were also recorded. Baseline health indicators, such as pre-existing medical conditions and vital signs upon admission, were documented. In addition, disease severity at presentation was assessed. This comprehensive approach provided a clear overview of each patient's status during their hospital stay.

Such data included clinical details, initial anthropometric measurements and nutrition-related laboratory tests. Malnutrition risk was also determined using the Malnutrition Screening Tool (MST) score. The MST is a rapid screening tool for assessing nutritional risk in hospitalised patients, focusing on recent unintentional weight loss and reduced food intake, in accordance with ESPEN guidelines [7,9].

At timepoint 2, all participants who agreed to participate in the study were invited for a post-COVID-19 follow-up visit. The assessments performed during this visit were specifically performed as part of this research and involved the following three parts: (1) face-to-face interview and questionnaire, used to assess the primary outcomes (fatigue and muscle pain), dietary habits and micronutrient supplement/ medicinal herb use; (2) anthropometric measurements, with body weight and height remeasured to calculate current BMI; and (3) laboratory investigations, determining post-recovery magnesium and vitamin D levels from collected blood samples.

Ethical Approval

This study was approved by the Research Ethics Standing Committee (REC) at the University of Ha'il (H-2021-251). Participants provided written informed consent prior to participating. This ensured that they fully understood the study's purpose, procedures and potential risks and benefits. To safeguard participant privacy, all collected data have been kept strictly confidential and anonymised. Access to the data is restricted to authorised researchers, and appropriate measures were implemented to protect the data from unauthorised access or disclosure.

Statistical Analysis

Statistical analysis was conducted using the Statistical Package for the Social Sciences (SPSS). Given the small sample size ($N=103$) and the extremely low prevalence of the primary outcomes in the cohort, traditional multivariable logistic regression modelling was avoided due to issues of mathematical instability and low sensitivity. Instead, the analysis focused on robust comparative and non-parametric tests to reliably quantify

associations.

The non-parametric Mann–Whitney U test was used to test the hypothesis that micronutrient levels are lower in patients with fatigue or muscle pain. Specifically, this involved comparisons of the median levels of continuous nutritional variables (magnesium and vitamin D between patients with and without persistent fatigue or muscle pain.

A chi-square test was used for all categorical/binary variables to compare proportions (e.g. malnutrition risk, supplement use) between patients with and without persistent fatigue. The Fisher's exact test or likelihood ratio statistics were utilized instead of the standard Pearson chi-square test when its underlying assumption was not met because the expected number of observations in some categories, or cells, was too low. Mann–Whitney U tests were used for continuous and ordinal questionnaire scores (e.g. ultra-processed food score, healthy eating self-rating, healthy eating adherence level) to compare median scores between the two groups.

3. Results

The sociodemographic characteristics of the 103 participants are summarised in Table 1. Of these, 71 had comorbidities and 32 did not. Among participants with comorbidities, 53.5% were female and 46.5% were male, whereas in the group without comorbidities, 43.8% were female and 56.2% were male. The mean age was significantly higher among participants with comorbidities (58.2 ± 13.2 years) than among those without them (48.23 ± 14.84 years; $p = 0.000$). With respect to educational attainment, a higher proportion of participants without comorbidities had completed college or university education (37.5%) compared with those with comorbidities (22.5%). Conversely, individuals with comorbidities were more likely to have had no formal schooling (26.8% vs. 12.5%).

Most participants were married, with a slightly higher proportion observed among those with comorbidities (87.3%) than among those without them (75.0%). Employment status varied considerably between the groups: 68.8% of participants without comorbidities were employed compared with only 32.4% of those with comorbidities. Monthly income distribution did not differ significantly between groups, with the majority in both groups reporting an income of 10,000 Saudi riyals (SAR) or less (64.8% with comorbidities vs. 65.6% without).

Table 2 illustrates the clinical characteristics of the participants during their hospitalisation for COVID-19. The mean length of stay in hospital was slightly longer among participants with comorbidities (10.11 ± 6.79 days) than among those without them (8.31 ± 4.65 days), although the difference was not statistically significant ($p = 0.434$). Most participants in both groups were admitted to a general medical ward rather than the intensive care unit. Tobacco smoking was reported by 9.9% of participants with comorbidities and 6.3% of those without them. The majority of COVID-19 cases in both groups were classified as moderate in severity (81.7% vs. 84.4%),

with a smaller proportion being severe.

Table 1. Sociodemographic Characteristics of the Participants

Variable	With Comorbidities (n=71)	Without Comorbidities (n=32)	p-value
Sex			
Female	38 (53.5)	14 (43.8)	
Male	33 (46.5)	18 (56.2)	
Age*	58.24±13.23	48.23±14.84	0.000
Level of education			
No formal education	22 (31)	4 (12.5)	
Completed primary school	8 (11.3)	2 (6.3)	
Completed intermediate school	6 (8.5)	5 (15.6)	
Completed high school	16 (22.5)	6 (18.8)	
Graduated from college/university	16 (22.5)	12 (37.5)	
Postgraduate degree	3 (4.2)	3 (9.4)	
Marital status			
Single	3 (4.2)	2 (6.3)	
Married	62 (87.3)	24 (75.0)	
Divorced	1 (1.4)	4 (12.5)	
Widowed	5 (7.0)	2 (6.3)	
Employment status over the past 12 months			
Employed	23 (32.4)	22 (68.8)	
Unemployed	48 (67.6)	10 (31.3)	
Monthly income			
10,000 SAR or less	46 (64.8)	21 (65.6)	
>10,000–15,000 SAR	21 (29.6)	10 (31.3)	
>15,000 SAR	4 (5.6)	1 (3.1)	
Data are presented as numbers and percentages			
*Data are presented as mean ± SD			
p-values of <0.05 are considered statistically significant.			

The most common comorbid conditions were type 2 diabetes (57.7%) and hypertension (47.9%), followed by type 1 diabetes, hypothyroidism, asthma (each 18.3%) and ischemic heart disease (12.7%). Participants with comorbidities had a significantly higher mean body mass index (31.79 ± 6.16 kg/m²) than those without them (29.68 ± 6.68 kg/m², $p = 0.037$), with obesity being more prevalent in the comorbid group (66.2% vs. 43.8%).

Malnutrition risk, based on MST score, was significantly higher among participants without comorbidities (50.0%) than among those with them (23.9%), with a higher mean malnutrition risk score in the non-comorbid group ($p = 0.018$). The most common symptoms during hospitalisation were shortness of breath, cough and fatigue, with similar distributions between the groups. The mean serum magnesium level was slightly lower in the comorbid group (0.79 ± 0.13 mmol/L) than in the non-comorbid group (0.84 ± 0.09 mmol/L; $p = 0.075$). All patients, however, had serum magnesium levels within the normal range. In addition, vitamin D levels were comparable between the groups ($p = 0.974$). Most participants in both groups had a deficiency or insufficiency of vitamin D. Nutritional supplement use was common, with multivitamins/minerals being the most frequently prescribed during hospitalisation and at discharge.

Table 2. Clinical Characteristics of Participants During Hospitalisation Due to COVID-19

Variable	With Comorbidities (n=71)	Without Comorbidities (n=32)	p-value
Length of hospital stay (days)*	10.11±6.79	8.31±4.65	0.434
Unit of admission			
General medical ward	66 (93.0)	30 (93.8)	
Intensive care unit	5 (7.0)	2 (6.3)	
Tobacco smoking	7 (9.9)	2 (6.3)	
Case severity			
Moderate	58 (81.7)	27 (84.4)	
Severe	13 (18.3)	5 (15.6)	
Main documented comorbid conditions			
Type 2 diabetes	41 (57.7)	-	
Hypertension	34 (47.9)	-	
Type 1 diabetes	13 (18.3)	-	
Hypothyroidism	13 (18.3)	-	
Asthma	13 (18.3)	-	
Ischemic heart disease	9 (12.7)	-	
COPD	2 (2.8)	-	
Pulmonary embolism	1 (1.4)	-	
Body mass index (kg/m ²) *	31.79±6.16	29.68±6.68	0.037
Weight status			
Normal	10 (14.1)	7 (21.9)	
Overweight	14 (19.7)	11 (34.4)	
Obesity	47 (66.2)	14 (43.8)	
Malnutrition risk based on MST score	17 (23.9)	16 (50.0)	
Malnutrition score*	0.72±1.28	1.4±1.45	0.018
COVID-19 symptoms	68 (95.8)	31 (96.9)	
Shortness of breath	57 (80.3)	25 (78.1)	
Cough	55 (77.5)	28 (87.5)	
Fatigue	15 (21.1)	9 (28.1)	
Muscle pain	9 (12.7)	5 (15.6)	
Sore throat	8 (11.3)	4 (12.5)	
Joint pain	5 (7.0)	1 (3.1)	
Headache	6 (8.5)	5 (15.6)	
Magnesium (mmol/L) *	0.79±0.13	0.84±0.09	0.075
Magnesium level classification			
Low (<0.66 mmol /L)	15 (21.1)	1 (3.1)	
Normal (0.66–1.07 mmol/L)	56 (78.9)	31 (96.9)	
Vitamin D25(OH) (ng/mL)*	20.41±11.17	20.19±9.66	0.974
Vitamin D25(OH) level classification			
Adequate (≥30 ng/mL)	18 (25.4)	9 (28.1)	
Insufficient (20–29 ng/mL)	19 (26.8)	4 (12.5)	
Deficient (<20 ng/mL)	34 (47.9)	19 (59.4)	
Nutritional supplements prescribed during hospitalisation			
Multivitamins/minerals	45 (63.4)	24 (75.0)	
Vitamin D	20 (28.2)	12 (37.5)	
Zinc	10 (14.1)	5 (15.6)	
Vitamin C	1 (1.4)	1 (3.1)	
Nutritional supplements prescribed at discharge			
Multivitamins/minerals	33 (46.5)	20 (62.5)	
Vitamin D	13 (18.3)	9 (28.1)	
Zinc	8 (11.3)	2 (6.3)	

Data are presented as frequencies and percentages, n (%).

*Data are presented as mean ± SD.

p-values of <0.05 are considered statistically significant.

Table 3. Clinical and Nutritional Characteristics of Participants 1–3 Years After Recovery from COVID-19

Variable	With Comorbidities (n=71)	Without Comorbidities (n=32)	p-value
Body mass index (kg/m ²) *	31.28±6.57	30.39±6.29	0.441
Weight status			
Underweight	2 (2.8)	0 (0.0)	
Normal	11 (15.5)	7 (21.9)	
Overweight	19 (26.8)	8 (25.0)	
Obesity	39 (54.9)	17 (53.1)	
Self-reported changes in body weight since diagnosis			
Increased	14 (19.7)	10 (31.3)	
Decreased	33 (46.5)	8 (25.0)	
No Change	24 (33.8)	14 (43.8)	
Post-recovery malnutrition risk based on MST score	33 (46.5)	11 (34.4)	
Post-recovery malnutrition score*	1.38±1.61	1.16±1.76	0.380
Post-recovery self-reported persistent COVID-19 symptoms	16 (22.5)	7 (21.9)	
Fatigue	5 (7.0)	5 (15.6)	
Muscle pain	14 (19.7)	1 (3.1)	
Self-reported changes in physical activity level since diagnosis			
Increased	4 (5.6)	0 (0.0)	
Decreased	42 (59.2)	21 (65.6)	
No Change	25 (35.2)	11 (34.4)	
Magnesium (mmol/L) *	0.78±0.11	0.84±0.095	0.008
Magnesium level classification			
Low (<0.66 mmol/L)	11 (15.5)	0 (0.0)	
Normal (0.66–1.07 mmol/L)	60 (84.5)	32 (100)	
Vitamin D25(OH) (ng/mL)*	29.49±13.37	28.33±10.9	0.770
Vitamin D25(OH) level classification			
Adequate (≥30 ng/mL)	37 (52.1)	15 (46.9)	
Insufficient (20–29 ng/mL)	19 (26.8)	11 (34.4)	
Deficient (<20 ng/mL)	15 (21.1)	6 (18.8)	
Currently taking nutritional supplements	40 (56.3)	7 (21.9)	
Self-reported types of nutritional supplements			
Multivitamins/minerals	12 (16.9)	6 (18.8)	
Vitamin D	19 (26.8)	4 (12.5)	
Zinc	1 (1.4)	0 (0.0)	
Vitamin C	3 (4.2)	0 (0.0)	
Vitamin B12	24 (33.8)	2 (6.3)	
B complex vitamins	3 (4.2)	0 (0.0)	
Omega 3	4 (5.6)	2 (6.3)	
Calcium	2 (2.8)	0 (0.0)	
Iron	2 (2.8)	0 (0.0)	
Self-reported use of herbal remedies during COVID-19 treatment period	23 (32.4)	13 (40.6)	
Honey	17 (23.9)	10 (31.3)	
Ginger	10 (14.1)	5 (15.6)	
Garlic	7 (9.9)	3 (9.4)	
Turmeric	1 (1.4)	1 (3.1)	
<i>Nigella sativa</i>	1 (1.4)	3 (9.4)	
Frankincense	1 (1.4)	0 (0.0)	
Self-reported current use of herbal remedies to boost immune system	17 (23.9)	8 (25.0)	
Honey	11 (15.5)	6 (18.8)	
Ginger	7 (9.9)	4 (12.5)	
Garlic	3 (4.2)	2 (6.3)	
Turmeric	1 (1.4)	1 (3.1)	
<i>Nigella sativa</i>	1 (1.4)	0 (0.0)	
Data are presented as frequency and percentages, n (%).			
*Data are represented as mean ± SD.			
p-values less than 0.05 are considered statistically significant.			

Table 3 presents the clinical and nutritional characteristics of participants 1–3 years after recovery from COVID-19. The two groups exhibited comparable

BMI values, with mean BMI of 31.28 ± 6.57 kg/m² among participants with comorbidities and 30.39 ± 6.29 kg/m² among those without them ($p = 0.441$). Obesity remained

common in both groups (54.9% and 53.1%, respectively). Regarding self-reported changes in body weight since diagnosis, the data showed that nearly half of the group with comorbidities (46.5%) had experienced weight loss, whereas weight gain was reported by 31.3% of the group without comorbidities and 19.7% of the group with them.

Post-recovery malnutrition risk, as assessed by the MST, was observed in 46.5% of participants with comorbidities and 34.4% of those without them. However, the difference in mean post-recovery MST scores between the two groups was not statistically significant ($p = 0.380$). Approximately one-fifth of participants in both groups (22.5% vs. 21.9%) reported persistent post-COVID-19 symptoms, with fatigue and muscle pain being the most common. A decline in physical activity levels was noted among the majority of participants, affecting 59.2% of those with comorbidities and 65.6% of those without them.

In terms of biochemical parameters, mean serum magnesium levels were significantly lower among participants with comorbidities (0.78 ± 0.11 mmol/L) than among those without them (0.84 ± 0.095 mmol/L; $p = 0.008$). In contrast, serum vitamin D levels did not differ significantly between the groups (29.49 ± 13.37 ng/mL vs. 28.33 ± 10.90 ng/mL; $p = 0.770$), although both magnesium and vitamin D levels remained at the lower edge of the optimal range. More than half of the participants with comorbidities (56.3%) reported current use of nutritional supplements, compared with 21.9% among those without comorbidities. Among individuals with comorbidities, vitamin B₁₂ (33.8%) and vitamin D (26.8%) were the most commonly used supplements, whereas multivitamin or multimineral preparations were for the participants without comorbidities.

Finally, the use of medicinal herbal remedies was also reported by a notable proportion of participants: 32.4% of those with comorbidities and 40.6% of those without them reported using such remedies. Honey and ginger were the most commonly used, followed by garlic. In the post-recovery phase, 23.9% of the comorbid group and 25.0% of the non-comorbid group reported continued use of herbal remedies for immune support, again with honey and ginger being the predominant choices.

The Mann-Whitney U test was used to investigate differences between patients reporting post-recovery muscle pain or fatigue ($N=23$) and those who did not ($N=80$) across a range of demographic, clinical and nutritional variables. The results revealed several significant associations (i.e. $p < 0.05$), as presented in Table 4.

In terms of demographic and clinical factors, the absence of post-recovery muscle pain/fatigue was significantly associated with both older age and a longer hospital stay. Specifically, patients who did not report fatigue were significantly older (mean rank: 55.6 vs. 39.3; $p = 0.022$) and had been hospitalised for significantly longer (mean rank: 56.24 vs. 37.26; $p = 0.007$). In contrast, the presence of muscle pain/fatigue showed no significant association with the patient's initial case severity during hospital admission ($p = 0.211$) or the presence of comorbidities ($p = 0.941$).

Regarding nutritional status and dietary habits, the fatigued and muscle pain group demonstrated clear indicators of poorer nutritional health. They exhibited a significantly higher risk of malnutrition, as reflected by a

higher post-recovery MST score (mean rank: 63.57 vs. 48.68; $p = 0.019$). Furthermore, adherence to recommended dietary servings was significantly poorer in the fatigued group based on three key metrics (where lower scores indicate higher adherence). The non-fatigue group showed significantly better overall adherence to the total score of main food groups (mean rank: 47.96 vs. 66.07; $p = 0.009$), as well as better specific adherence to recommended servings of cereals/bread ($p = 0.002$) and fruit ($p = 0.011$). No significant differences were found for post-recovery BMI or for the MST scores for vegetables, meat/protein or ultra-processed food.

Table 4. Post-COVID Recovery Profile: Factors Associated with Persistent Muscle Pain and / or Fatigue

Variable	Without Muscle Pain & Fatigue (n=80)	With Muscle Pain & Fatigue (n=23)	Z	p-value
Age (years)	55.63	39.39	-2.297	0.022**
Length of hospital stay (days)	56.24	37.26	-2.691	0.007**
Case severity	53.3	47.48	-1.252	0.211
Comorbidities	51.91	52.33	-0.074	0.941
II. Laboratory Values (Admission & Post-Recovery)				
Magnesium at admission (mmol/L)	54.11	44.65	-1.34	0.18
Post-recovery magnesium (mmol/L)	54.85	42.09	-1.811	0.07
Vitamin D at admission (ng/mL)	52.33	50.85	-0.21	0.834
Vitamin D post-recovery (ng/mL)	53.79	45.78	-1.133	0.257
III. Nutritional & Anthropometric Status				
Post-recovery malnutrition screening score	48.68	63.57	-2.337	0.019**
Post-recovery body mass index (kg/m ²)	53.34	47.35	-0.847	0.397
IV. Dietary Adherence Scores*				
Total adherence score (main food groups)	47.96	66.07	-2.605	0.009**
Cereal/bread servings score	47.63	67.22	-3.099	0.002**
Fruit servings score	48.74	63.35	-2.534	0.011**
Vegetable servings score	53.54	46.63	-1.332	0.183
Meat/protein servings score	52.93	48.78	-0.715	0.475
Ultra-processed food consumption score	50.59	56.89	-0.923	0.356
V. Supplements and Herbs				
Prescribed vitamin D (during hospitalisation and at discharge)	52.46	50.41	-0.344	0.731
Prescribed multivitamins/minerals (during hospitalisation and at discharge)	50.05	58.78	-1.622	0.105
Current use of complementary or alternative medicinal herbs	51.73	52.93	-0.229	0.819
*For dietary adherence variables (total adherence, cereal/bread, fruit, vegetable, meat/protein), a lower score indicates higher adherence to the recommended servings. **p-values of <0.05 are considered statistically significant.				

Finally, in the biochemical and micronutrient supplementation analysis, there were no significant differences between the groups in all admission and post-

recovery levels for both magnesium and vitamin D, although post-recovery magnesium showed a marginal trend towards lower levels in the fatigued group ($p = 0.070$). Similarly, the prescription of multivitamins/minerals or the current use of complementary and alternative medicinal herbs was not significantly associated with post-recovery muscle pain or fatigue.

4. Discussion

To the best of our knowledge, the current study is the first to investigate trends in dietary intake after acute COVID-19 infection in Ha'il region, KSA. The obtained findings offer new insights into the long-term nutritional profile of COVID-19 survivors, emphasising the relationships of malnutrition risk, diet quality and micronutrient levels with persistent fatigue and muscle pain. The results reveal that malnutrition risk and poor diet remain prevalent even 1–3 years after recovery from the acute infectious phase, suggesting that shortcomings in nutritional rehabilitation are common following acute infection.

Older age, chronic health conditions, and obesity were more common among patients hospitalized with COVID-19, consistent with previous literature identifying these factors as strong determinants of disease severity and long-term sequelae [37]. Older age, chronic health conditions, and obesity were more common among patients hospitalized with COVID-19, consistent with previous literature identifying these factors as strong determinants of disease severity and long-term sequelae [37]. Participants with these underlying conditions also had higher BMI values, reflecting metabolic risk factors that may negatively influence recovery. The findings also revealed the impact of social factors on health, with employment and education levels being associated with the presence of comorbid conditions, consistent with reports showing that a socioeconomically disadvantaged status amplifies the burden of long-COVID symptoms and nutritional risk [38]. Although the average hospital stay was longer for participants with comorbidities, this difference did not reach statistical significance. Nonetheless, prolonged hospitalisation is a known predictor of malnutrition and post-acute sarcopenia due to reduced intake and inflammation-induced catabolism [39].

A key observation in this study is that malnutrition risk during hospitalisation was significantly higher in participants without comorbidities than in those with them. This suggests that even patients without chronic diseases may experience substantial nutritional vulnerability during COVID-19 infection, which could predispose them to poorer recovery outcomes. Concerning post-recovery assessments in our cohort, our findings showed that patients with comorbidities reporting persistent fatigue or muscle pain had higher malnutrition scores [13].

The persistence of malnutrition risk in nearly half of our participants aligns with previous evidence indicating that approximately one-third to nearly half of adults after COVID-19 infection remain at risk of malnutrition several months after discharge [40]. This ongoing vulnerability may be driven by persistent inflammation, dysgeusia, appetite loss and fatigue, which could limit the ability to

prepare and consume food. Indeed, Gobbi et al. [14] found that 60% of post-acute COVID-19 patients were malnourished.

In our cohort, fatigue and muscle pain were significantly associated with higher malnutrition screening scores and poorer adherence to dietary recommendations, particularly regarding the intake of cereal/bread and fruit. These findings suggest that dietary inadequacy may contribute to the persistence of post-viral fatigue through insufficient energy and micronutrient intake, aligning with recent evidence that suboptimal dietary patterns—especially low consumption of fruit and whole grain—are linked to increased risk of post-viral fatigue and cognitive decline among long-COVID patients [41,42]. Consistent with this, the strongest physiological determinants of persistent post-recovery muscle pain and fatigue in our analysis were markers of chronic nutritional depletion, with individuals exhibiting persistent symptoms 1–3 years post-infection demonstrating significantly higher post-recovery MST mean scores indicating ongoing nutritional risk. This chronic vulnerability suggests that sustained symptoms are functionally linked to an inability to maintain adequate nutritional status and energy balance, as malnutrition reduces available energy reserves and exacerbates cognitive impairments relevant to myalgic encephalomyelitis/chronic fatigue syndrome and long COVID [43]. Poor adherence to a diet high in essential energy-rich food groups, such as cereals and bread (containing complex carbohydrates), may further exacerbate the bioenergetic failure underlying persistent post-recovery muscle pain and fatigue. Similarly, insufficient fruit intake suggests deficiencies in the vitamins, minerals and antioxidants required to mitigate chronic systemic inflammation implicated in post-acute sequelae of SARS-CoV-2 [44]. The data strongly suggest that nutritional deficiency is a major, modifiable correlate of post-acute sequelae of SARS-CoV-2 persistence, necessitating rigorous dietary intervention.

In terms of micronutrients, our findings revealed that magnesium levels were significantly lower among patients with comorbidities. Similarly, a study by Zhu et al. reported that serum magnesium levels were significantly decreased in the critical group of SARS CoV-2 patients compared with the levels in other groups [45]. Magnesium deficiency is a well-established complication of type 2 diabetes and hypertension, primarily driven by the wasting of magnesium by the kidneys due to chronic hyperglycaemia and vitamin D deficiency [46]. Furthermore, low serum magnesium has been shown to be associated with a higher incidence of long-COVID symptoms [47]. Therefore, post-COVID-19 monitoring must include targeted assessment of magnesium to mitigate chronic cardiovascular and metabolic complications.

In addition, in this study, vitamin D deficiency remained highly prevalent at both hospital admission and follow-up, although between-group differences were not significant. This mirrors numerous studies reporting widespread vitamin D deficiency among COVID-19 survivors [48]. Vitamin D is critical for muscle function and immune modulation; however, supplementation trials show mixed benefits in improving long-COVID outcomes. Nonetheless, a 2022 randomised trial by Khorasanchi et al. in Iran demonstrated that correcting vitamin D deficiency

improved inflammatory biomarkers [49]. The present findings are consistent with that evidence, suggesting that while vitamin D insufficiency remains common, its correction alone may be insufficient to resolve long-COVID manifestations without broader dietary and metabolic support.

The widespread use of nutritional supplements observed in our cohort, particularly multivitamins / minerals and vitamin D, mirrors global patterns of self-directed nutritional management during and after the COVID-19 pandemic. Supplement use was especially common among individuals with comorbidities, who reported higher consumption of these products, possibly as a strategy for self-managing persistent fatigue and neuropathy—symptoms frequently associated with long COVID [50]. However, evidence regarding the efficacy of non-prescribed supplements remains inconclusive, and excessive consumption may be harmful because it can cause micronutrient imbalances.

Among the subjects in this study, the use of herbal remedies was common during the acute phase (32.4% among those with comorbidities, 40.6% among those without them) and continued post-recovery (23.9% vs. 25.0%), with honey and ginger being the overwhelmingly predominant choices in both periods [50]. This pattern reflects the strong cultural reliance on traditional, complementary and integrative medicine for managing viral and inflammatory symptoms in KSA. Ginger's pain-reducing effects are attributed to its high anti-inflammatory capacity, which has been shown to exhibit pharmacological efficacy comparable to that of non-steroidal anti-inflammatory drugs [51], while honey may exert therapeutic effects through the direct inhibition of SARS-CoV-2 or by enhancing the immune response [52]. Substances such as honey, ginger and garlic as used by those included in this study. Although these substances possess antioxidant and anti-inflammatory properties [50,53], their continued popularity underscores the importance of healthcare professionals integrating culturally accepted complementary practices into patient education while simultaneously promoting evidence-based nutritional guidance.

Despite this widespread use of traditional remedies, the current analysis found no significant association between the use of complementary and alternative medicines and herbs and the resolution of persistent post-acute sequelae of SARS-CoV-2 symptoms, suggesting that while some dietary supplements show potential in reducing fatigue and muscle pain, methodological limitations and inconsistent results obstruct the drawing of definitive conclusions regarding their efficacy in established post-viral pathology.

Overall, our findings support the hypothesis that nutritional vulnerability persists beyond the acute phase of COVID-19 infection. Consistent with the recommendations by Cederholm et al. [6,7,8], we emphasise the importance of systematic post-discharge nutritional screening and individualised dietary counselling to ensure both macronutrient balance and micronutrient adequacy. Routine assessment of malnutrition risk, along with monitoring of key nutrients such as magnesium and vitamin D, should be incorporated into long-COVID follow-up care—particularly for older

adults and those with metabolic comorbidities. Personalised dietary interventions focusing on energy sufficiency, balanced macronutrient distribution and micronutrient-dense foods may help alleviate lingering fatigue and muscle pain. Notably, since fatigue in our cohort was associated with overall dietary quality rather than directly with serum vitamin D or magnesium levels, comprehensive nutritional rehabilitation may be more beneficial than supplementation alone. Integrating dietitians into multidisciplinary long-COVID care pathways could therefore optimise recovery outcomes and reduce the burden of persistent symptoms.

Several limitations of this work must be acknowledged. First, the sample size was relatively small (N=103), which limited the statistical power and prevented the use of multivariable models to control confounding factors. This study features patients living in a single region of Saudi Arabia, so its findings may not be fully generalizable. Second, the data on dietary intake and supplement use relied partially on self-reports, which may introduce recall bias. The retrospective component also depended on the completeness of medical records, limiting the accuracy of the baseline nutritional assessment.

An additional limitation of this work is the use of the MST score as a proxy for nutritional risk; while the MST has been validated for clinical screening, it does not capture detailed dietary intake or nutrient adequacy. Serum magnesium and vitamin D were the only biochemical markers measured, leaving other relevant micronutrients (e.g. zinc, selenium, B vitamins) unexamined. Finally, the cross-sectional nature of post-recovery assessment prevents the drawing of causal inferences regarding the directionality of associations between dietary quality, micronutrient status and persistent symptoms.

5. Conclusion

In summary, this study on long COVID in KSA shows that malnutrition risk and suboptimal dietary patterns can persist for up to three years after recovery from COVID-19 infection, even without obvious deficiencies in vitamin D and magnesium. Fatigue and muscle pain are more closely associated with overall nutritional inadequacy and poor dietary adherence than with individual micronutrient levels. These findings underscore the importance of comprehensive nutritional rehabilitation strategies, including dietary education, monitoring of key micronutrients and the integration of culturally appropriate health behaviours to support long-term recovery in post-COVID patients.

Addressing nutritional vulnerabilities through early screening and tailored interventions may improve recovery trajectories, reduce symptom persistence and enhance overall quality of life among COVID-19 survivors. Future studies with larger, multicentre cohorts and longitudinal designs are needed to further elucidate the causal pathways linking nutrition and long-COVID outcomes.

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Data Availability Statement: Data will be available from the authors as requested.

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