ISSN 0973-2063 (online) 0973-8894 (print)
Bioinformation 22(10): 7537-7542 (2026)
©Biomedical Informatics (2026)

BIOINFORMATION
Discovery at the interface of physical and biological sciences
BIOMEDICAL INFORMATICS
www.bioinformation.net
Volume 22(10)
Research Article

Received October 1, 2026; Revised October 31, 2026; Accepted October 31, 2026, Published October 31, 2026
DOI: 10.6026/973206300227537

SJIF 2026 (Scientific Journal Impact Factor for 2026) = 8.478
2022 Impact Factor (2023 Clarivate Inc. release) is 1.9

Declaration on Publication Ethics:
The author's state that they adhere with COPE guidelines on publishing ethics as described elsewhere at https://publicationethics.org/. The authors also undertake that they are not associated with any other third party (governmental or non-governmental agencies) linking with any form of unethical issues connecting to this publication. The authors also declare that they are not withholding any information that is misleading to the publisher in regard to this article.

Declaration on official E-mail:
The corresponding author declares that lifetime official e-mail from their institution is not available for all authors

License statement:
This is an Open Access article which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly credited. This is distributed under the terms of the Creative Commons Attribution License

Comments from readers:
Articles published in BIOINFORMATION are open for relevant post publication comments and criticisms, which will be published immediately linking to the original article without open access charges. Comments should be concise, coherent and critical in less than 1000 words.

Disclaimer:
Bioinformation provides a platform for scholarly communication of data and information to create knowledge in the Biological/ Biomedical domain after adequate peer/editorial reviews and editing entertaining revisions where required. The views and opinions expressed are those of the author(s) and do not reflect the views or opinions of Bioinformation and (or) its publisher Biomedical Informatics. Biomedical Informatics remains neutral and allows authors to specify their address and affiliation details including territory where required.

Edited by Ritik Kashwani
E-mail: docritikkashwani@yahoo.com
Citation: Yadav *et al*. Bioinformation 22(10): 7537-7542 (2026)

Evaluation of nutritional deficiencies and muscle weakness in post-COVID rehabilitation patients

Natasha Yadav[1,*], Vikash Kumar Tiwari[2], Amit Vasant Deshpande[3], Parth Jani[4], Pierina Inés Cantos Márquez[5], Luis Patricio Davila Aguilar[6], Doménica Nicolle Bastidas León[6] & Jeff Walter Rajadurai[7]

[1]Department of Dravyaguna Vigyan (Ayurveda),State Government Ayurveda Yoga and Naturopathy College, Jaipur, Rajasthan, India; [2]Department of Physiology, Autonomous State Medical College (ASMC), Lakhimpur Kheri, Uttar Pradesh, India; [3]Department of Community Medicine, Datta Meghe Medical College, Datta Meghe Institute of Higher Education and Research, Wanadongri, Nagpur, Maharashtra, India; [4]Department of General Medicine, Government Medical College, Bhavnagar, Gujarat, India; [5]Department of Medicine, University of Guayaquil, Ecuador, South America; [6]Department of Nutrition and Dietetics, Armed Forces Specialty Hospital No. 1 (Hospital de Especialidades de las Fuerzas Armadas No. 1), Quito, Ecuador, South America; [7]Department of Orthopaedics, Madha Medical College & Research Institute, Chennai, Tamil Nadu, India; *Corresponding author

ISSN 0973-2063 (online) 0973-8894 (print)
Bioinformation 22(10): 7537-7542 (2026)
©Biomedical Informatics (2026)

Affiliation URL:
https://department.rajasthan.gov.in/jankalyan-category-and-entry-type/221/65/489
https://asmclakhimpurkheri.in/
https://dmiher.edu.in/dmmc
https://gmcbhavnagar.edu.in/
http://fcm.ug.edu.ec/
https://site.hospitalmilitar.mil.ec/
https://mmcri.in/

Author contact:
Natasha Yadav - E-mail: drnatashayadav@gmail.com
Vikash Kumar Tiwari - E-mail: drvikashkt@gmail.com
Amit Vasant Deshpande - E-mail: amitvd1977@gmail.com
Parth Jani - E-mail: parthjani13@gmail.com
Pierina Inés Cantos Márquez - E-mail: pierina094@gmail.com
Luis Patricio Davila Aguilar - E-mail: patovenmd@hotmail.com
Doménica Nicolle Bastidas León - E-mail: domebastidas@hotmail.com
Jeff Walter Rajadurai - E-mail: jeffy.walter@gmail.com

Abstract:
Persistent nutritional deficiencies and muscle weakness are common in post-COVID syndrome and may impair functional recovery and quality of life. A prospective observational study included 100 adult post-COVID rehabilitation patients over 12 months. Nutritional status, handgrip strength, Medical Research Council scores and Barthel Index were assessed, along with serum vitamin D, vitamin B12, hemoglobin, albumin and ferritin and C reactive protein levels. Vitamin D deficiency was present in 64% of participants and was associated with lower handgrip strength (18.9 ± 5.2 vs. 26.7 ± 5.8 kg, $p<0.001$), while vitamin B12 deficiency and hypoalbuminemia occurred in 38% and 29%, respectively. Thus, nutritional deficiencies were associated with impaired muscle strength and functional performance, supporting early nutritional assessment and targeted supplementation during post-COVID rehabilitation.

Keywords: Post-COVID syndrome, nutritional deficiency, vitamin D, muscle weakness, rehabilitation, handgrip strength, functional recovery

Background:
Coronavirus disease 2019 (COVID-19) can produce persistent health consequences beyond the acute phase of infection **[1]**. A proportion of COVID-19 survivors develop persistent symptoms collectively referred to as post-COVID condition or long COVID **[2]**. Common manifestations include fatigue, reduced exercise capacity, muscle weakness, cognitive difficulties and impaired quality of life **[2, 3]**. These persistent symptoms can interfere with physical functioning and increase the need for structured rehabilitation **[4]**. Muscle weakness after COVID-19 may result from systemic inflammation, prolonged immobilization, critical illness, corticosteroid exposure, reduced physical activity and inadequate nutritional intake **[5, 6]**. Patients requiring intensive care are particularly vulnerable to muscle wasting because of prolonged bed rest, mechanical ventilation and systemic catabolic stress. Reduced muscle strength has also been reported among patients recovering from non-critical COVID-19, indicating that functional impairment may persist beyond hospitalization **[7]**. Nutritional abnormalities are frequently reported in patients recovering from COVID-19 and may contribute to impaired physical recovery **[8]**. Vitamin D deficiency has been associated with impaired muscle function and reduced physical performance, while deficiencies of vitamin B12, iron and other nutrients can contribute to fatigue and neuromuscular dysfunction **[9, 10]**. Therefore, it is of interest to evaluate the prevalence of nutritional deficiencies among post-COVID rehabilitation patients and to show their association with muscle weakness and functional recovery.

Methodology:
Study design and setting:
A prospective observational cross-sectional study was conducted in the Department of Physical Medicine and Rehabilitation in collaboration with the Department of General Medicine and Clinical Biochemistry at a tertiary care teaching hospital over a period of 12 months. Ethical approval was obtained from the Institutional Ethics Committee before commencement of the study. Written informed consent was obtained from all participants.

Study population:
Adult patients attending the post-COVID rehabilitation clinic after confirmed SARS-CoV-2 infection were consecutively screened for eligibility. COVID-19 infection had been confirmed previously by RT-PCR or rapid antigen testing. Patients were enrolled between four weeks and six months following recovery from acute infection.

Sample size:
A total of 100 post-COVID rehabilitation patients fulfilling the eligibility criteria were included in the study. The sample size was determined considering the expected prevalence of nutritional deficiencies among post-COVID survivors with a 95% confidence level and adequate statistical precision.

Inclusion criteria:
[1] Adults aged 18 years and above.
[2] Previous laboratory-confirmed COVID-19 infection.
[3] Patients attending post-COVID rehabilitation within six months of recovery.
[4] Persistent complaints of fatigue, reduced exercise tolerance, or muscle weakness.
[5] Patients willing to provide written informed consent.

Exclusion criteria:
[1] Pre-existing neuromuscular disorders.
[2] Chronic kidney disease stage IV or above.
[3] Chronic liver disease.
[4] Active malignancy.
[5] Autoimmune muscle disorders.
[6] Pregnancy.
[7] Patients receiving long-term nutritional supplementation before COVID-19.
[8] Incomplete laboratory investigations.

Data collection:
After obtaining informed consent, demographic information including age, sex and occupation, smoking history, alcohol intake, comorbidities and duration since COVID-19 recovery, hospitalization history, oxygen therapy, intensive care admission and corticosteroid exposure were recorded. Anthropometric measurements including height, weight, body mass index (BMI), mid-arm circumference and calf circumference were measured using standardized protocols.

Clinical assessment:
Muscle strength was evaluated using:
[1] Medical Research Council (MRC) Muscle Strength Scale
[2] Handgrip Strength Test using a calibrated dynamometer
[3] Five Times Sit-to-Stand Test (5STS)
[4] Six-Minute Walk Test (6MWT)

Functional independence was assessed using the Barthel Index. Fatigue severity was assessed using the Fatigue Severity Scale (FSS).

Laboratory investigations:
Venous blood samples were collected after overnight fasting for estimation of:
[1] Complete blood count
[2] Hemoglobin
[3] Serum Vitamin D (25-hydroxyvitamin D)
[4] Serum Vitamin B12
[5] Serum Ferritin
[6] Serum Albumin
[7] Serum Calcium
[8] Serum Iron
[9] Total Iron Binding Capacity (TIBC)
[10] C-Reactive Protein (CRP)
[11] Erythrocyte Sedimentation Rate (ESR)
[12] Serum Creatinine
[13] Liver Function Tests

Vitamin D deficiency was defined as serum 25(OH) D levels <20 ng/mL. Vitamin B12 deficiency was defined as serum vitamin B12 levels <200 pg/mL. Hypoalbuminemia was defined as serum albumin <3.5 g/dL. Anemia was defined according to World Health Organization criteria.

Outcome measures:
Primary outcomes:
[1] Prevalence of nutritional deficiencies.
[2] Muscle strength measured by handgrip dynamometry.
[3] Medical Research Council muscle strength score.

Secondary outcomes:
[1] Functional independence assessed by Barthel Index.
[2] Association between nutritional biomarkers and muscle weakness.
[3] Predictors of severe muscle weakness.

Statistical analysis:
Data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics version 26.0. Continuous variables were expressed as mean ± standard deviation, whereas categorical variables were presented as frequency and percentage. Independent Student's t-test and one-way analysis of variance were used for continuous variables. Chi-square or Fisher's exact tests were used for categorical variables. Pearson correlation analysis evaluated associations between nutritional biomarkers and muscle strength. Multivariable logistic regression analysis identified independent predictors of severe muscle weakness. A p-value <0.05 was considered statistically significant.

Results:
A total of 100 post-COVID rehabilitation patients were included in the study. The mean age of the participants was 49.8 ± 13.2 years, with males constituting 56% of the study population. Nearly half of the participants had at least one underlying comorbidity, most commonly diabetes mellitus and hypertension. Approximately 61% had required hospitalization during acute COVID-19 infection, while 22% had received intensive care treatment **(Table 1).** Laboratory evaluation showed that vitamin D deficiency was the most common nutritional abnormality, followed by anemia, vitamin B12 deficiency and hypoalbuminemia **(Table 2).** Muscle strength assessment showed persistent weakness among a substantial proportion of post-COVID patients despite completion of the acute illness **(Table 3).** Vitamin D deficiency demonstrated a significant association with reduced muscle strength and poorer

functional recovery **(Table 4).** Patients with vitamin B12 deficiency also demonstrated poorer rehabilitation outcomes **(Table 5).** Patients with hypoalbuminemia exhibited significantly poorer muscle performance than those with normal serum albumin **(Table 6).** Correlation analysis demonstrated positive associations between nutritional biomarkers and muscle performance, while inflammatory markers (CRP and ferritin) were negatively correlated with handgrip strength **(Table 7).** Multivariable logistic regression identified vitamin D deficiency, hypoalbuminemia, vitamin B12 deficiency and ICU admission as independent predictors of severe muscle weakness **(Table 8)**. The overall prevalence of nutritional abnormalities among post-COVID rehabilitation patients is summarized in **Table 9.**

Table 1: Baseline demographic and clinical characteristics (n=100)

Variable	Value
Age (years), Mean ± SD	49.8 ± 13.2
Male, n (%)	56 (56.0)
Female, n (%)	44 (44.0)
BMI (kg/m²), Mean ± SD	25.9 ± 4.6
Diabetes mellitus, n (%)	34 (34.0)
Hypertension, n (%)	31 (31.0)
Hospitalized during COVID-19, n (%)	61 (61.0)
ICU admission, n (%)	22 (22.0)
Corticosteroid therapy, n (%)	47 (47.0)
Duration since recovery (weeks), Mean ± SD	9.4 ± 3.8

Table 2: Nutritional profile of participants

Parameter	Mean ± SD / n (%)
Vitamin D (ng/mL)	18.6 ± 7.9
Vitamin D deficiency	64 (64.0)
Vitamin B12 (pg/mL)	278.5 ± 112.8
Vitamin B12 deficiency	38 (38.0)
Hemoglobin (g/dL)	11.8 ± 1.9
Anemia	42 (42.0)
Serum Albumin (g/dL)	3.7 ± 0.6
Hypoalbuminemia	29 (29.0)
Ferritin (ng/mL)	268.4 ± 104.8
Elevated CRP	36 (36.0)

Table 3: Muscle strength and functional assessment

Parameter	Mean ± SD
Handgrip strength (kg)	21.7 ± 6.5
MRC muscle score	50.6 ± 5.8
Five Times Sit-to-Stand (seconds)	15.3 ± 4.7
Six-Minute Walk Distance (m)	358.4 ± 82.6
Barthel Index	82.4 ± 11.8
Fatigue Severity Scale	4.9 ± 1.4

Table 4: Association between Vitamin D deficiency and muscle strength

Variable	Vitamin D Deficient (n=64)	Normal Vitamin D (n=36)	p-value
Handgrip strength (kg)	18.9 ± 5.2	26.7 ± 5.8	<0.001
MRC score	48.8 ± 5.4	53.8 ± 4.6	<0.001
Six-minute walk distance (m)	331.8 ± 71.5	405.6 ± 68.3	<0.001
Barthel Index	78.6 ± 10.8	89.3 ± 8.6	<0.001

Table 5: Association between Vitamin B12 deficiency and rehabilitation outcomes

Variable	B12 Deficient (n=38)	Normal B12 (n=62)	p-value
Handgrip strength (kg)	19.5 ± 5.6	23.1 ± 6.2	0.004
MRC score	49.0 ± 5.5	51.7 ± 5.2	0.018
Barthel Index	79.8 ± 10.9	84.6 ± 10.2	0.031
Fatigue Severity Scale	5.4 ± 1.3	4.6 ± 1.2	0.002

Table 6: Association between serum albumin and muscle strength

Variable	Albumin <3.5 g/dL (n=29)	Albumin ≥ 3.5 g/dL (n=71)	p-value
Handgrip strength (kg)	18.2 ± 4.9	23.4 ± 6.3	<0.001
MRC score	47.9 ± 5.7	51.7 ± 5.1	0.001
Barthel Index	76.8 ± 10.6	84.8 ± 10.2	0.001

Table 7: Correlation of nutritional parameters with handgrip strength

Variable	Correlation (r)	p-value
Vitamin D	0.61	<0.001
Vitamin B12	0.39	<0.001
Serum Albumin	0.46	<0.001
Hemoglobin	0.41	<0.001
CRP	-0.42	<0.001
Ferritin	-0.29	0.004

Table 8: Multivariable logistic regression for severe muscle weakness

Variable	Adjusted OR	95% CI	p-value
Vitamin D deficiency	3.86	1.68–8.87	0.001
Hypoalbuminemia	2.94	1.24–6.98	0.014
Vitamin B12 deficiency	2.18	1.01–4.73	0.046
Diabetes mellitus	1.86	0.89–3.88	0.102
ICU admission	2.57	1.16–5.72	0.020
Age >60 years	1.54	0.71–3.33	0.274

Table 9: Overall prevalence of nutritional abnormalities

Nutritional abnormality	n (%)
Vitamin D deficiency	64 (64.0)
Vitamin B12 deficiency	38 (38.0)
Hypoalbuminemia	29 (29.0)
Anemia	42 (42.0)
Elevated CRP	36 (36.0)
Elevated Ferritin	33 (33.0)

Discussion:

The present study evaluated the prevalence of nutritional deficiencies and their association with muscle weakness among post-COVID rehabilitation patients. Vitamin D deficiency was the most common nutritional abnormality, affecting 64% of participants, followed by anemia, vitamin B12 deficiency and hypoalbuminemia. Patients with vitamin D deficiency demonstrated significantly reduced handgrip strength, lower Medical Research Council (MRC) muscle strength scores, shorter six-minute walk distances and lower Barthel Index scores than patients with normal vitamin D levels. Furthermore, serum vitamin D, vitamin B12, hemoglobin and albumin showed significant positive correlations with muscle strength, whereas inflammatory markers demonstrated negative correlations. These findings emphasize the importance of comprehensive nutritional assessment during post-COVID rehabilitation. Our findings are consistent with those reported by Simón-Frapolli *et al*. **[11]**, who investigated vitamin D status and morph functional recovery in post-critical COVID-19 survivors. Their prospective study showed that vitamin D deficiency was associated with prolonged hospitalization; greater systemic inflammation, lower skeletal muscle mass, reduced handgrip strength and poorer six-minute walk performance during rehabilitation. Patients with adequate vitamin D levels exhibited significantly greater improvements in muscle strength and functional recovery over six months. Similarly, the present study observed markedly lower handgrip strength and poorer functional outcomes among vitamin D-deficient patients, supporting the role of vitamin D in

skeletal muscle recovery following COVID-19. The beneficial role of nutritional rehabilitation observed in our study is further supported by Bradbury *et al.* (2023) **[12]**, who performed a systematic scoping review evaluating nutritional interventions in long COVID. The authors concluded that persistent inflammation, malnutrition, sarcopenia and micronutrient deficiencies are common among patients with prolonged COVID-19 symptoms and highlighted nutritional rehabilitation as an essential component of multidisciplinary recovery programmes. They emphasized that vitamin D; B-complex vitamins, adequate protein intake and individualized nutritional supplementation may improve muscle recovery and reduce fatigue. Likewise, our findings demonstrate that deficiencies of vitamin D, vitamin B12 and serum albumin were independently associated with poorer muscle strength and rehabilitation outcomes. The improvement in functional performance observed among nutritionally adequate patients is also consistent with the meta-analysis by Oliveira *et al.* (2024) **[13]**, which evaluated pulmonary rehabilitation programmes for post-COVID syndrome. Their analysis showed significant improvements in six-minute walk distance and fatigue following rehabilitation, although improvements in peripheral muscle strength varied across studies. The authors suggested that persistent nutritional deficits and systemic inflammation may partly explain incomplete recovery of muscle strength despite rehabilitation. Our study complements these observations by demonstrating that nutritional deficiencies, particularly vitamin D deficiency and hypoalbuminemia, independently predict persistent muscle weakness during rehabilitation, highlighting the need to integrate nutritional management with conventional rehabilitation programmes. Recent evidence by Saunders *et al.* (2025) **[14]** further supports our observations. In their scoping review of rehabilitation interventions for post-COVID condition, the authors reported that multidisciplinary rehabilitation strategies incorporating nutritional optimization, physical exercise and individualized patient assessment consistently improved functional recovery and quality of life. They emphasized that nutritional evaluation should be incorporated into routine rehabilitation because persistent fatigue, muscle weakness and reduced physical performance are frequently associated with underlying nutritional compromise. The present study similarly demonstrates that patients with nutritional deficiencies had significantly lower Barthel Index scores, reduced exercise capacity and greater fatigue severity, reinforcing the value of integrated rehabilitation approaches. Our findings also agree with the observations of Perestiuk *et al.* (2025) **[15]**, who evaluated vitamin D status and long COVID manifestations in hospitalized children. Although conducted in a pediatric population, their prospective cohort study demonstrated that vitamin D deficiency significantly increased the risk of developing long COVID symptoms, particularly musculoskeletal and neurological manifestations. Children with vitamin D deficiency experienced longer hospital stays and were more likely to develop persistent fatigue and muscle-related symptoms than those with adequate vitamin D concentrations. Although our study involved adults undergoing rehabilitation, both investigations consistently demonstrate that vitamin D deficiency contributes to persistent post-COVID musculoskeletal dysfunction and delayed functional recovery **[16, 17]**.

Conclusion:

Nutritional deficiencies, particularly vitamin D deficiency, vitamin B12 deficiency, anemia and hypoalbuminemia, were common among post-COVID rehabilitation patients. These deficiencies were associated with reduced muscle strength, impaired functional capacity and greater fatigue severity. Routine nutritional screening and individualized nutritional management alongside structured rehabilitation may improve functional recovery and long-term outcomes.

Summary of findings:

Among the 100 post-COVID rehabilitation patients, vitamin D deficiency was the most prevalent nutritional abnormality (64%), followed by anemia (42%), vitamin B12 deficiency (38%) and hypoalbuminemia (29%), elevated CRP (36%) and elevated ferritin (33%). Patients with vitamin D deficiency had significantly lower handgrip strength, MRC scores, six-minute walk distances and Barthel Index scores than those with normal vitamin D levels (all $p<0.001$). Significant positive correlations were observed between vitamin D, vitamin B12, serum albumin, hemoglobin and muscle strength, whereas inflammatory markers showed negative correlations. Multivariable logistic regression identified vitamin D deficiency, hypoalbuminemia, vitamin B12 deficiency and previous ICU admission as independent predictors of severe muscle weakness.

Limitations:

The present study has several limitations. First, it was conducted at a single tertiary care center with a relatively small sample size of 100 participants, which may limit the generalizability of the findings to broader populations. Second, the cross-sectional observational design precluded assessment of causal relationships between nutritional deficiencies and muscle weakness or evaluation of long-term rehabilitation outcomes. Third, pre-COVID nutritional status and muscle strength data were unavailable, making it difficult to determine the extent to which these abnormalities were attributable to COVID-19. Additionally, dietary intake, physical activity, socioeconomic status and adherence to nutritional supplementation during rehabilitation were not evaluated, although these factors may have influenced recovery. Finally, long-term follow-up was not performed to assess the sustained impact of nutritional interventions on muscle strength and functional improvement.

References:

[1] López-Sampalo A *et al. Rev Clin Esp (Barc).* 2022 **222:**241**. [PMID: 35260380]**
[2] Del Rio C *et al. JAMA.* 2020 **324**:1723**. [PMID: 33031513]**
[3] Sweis JJG *et al. Int J Environ Res Public Health.* 2024 **21**:325**. [PMID: 38541324]**
[4] Xie K *et al. J Thorac Dis.* 2025 **17**:7414**. [PMID: 41158347]**
[5] Pavli A *et al. Arch Med Res.* 2021 **52**:575**. [PMID: 33962805]**

[6] Almeida IDS *et al. PLoS One.* 2025 **20**:e0332242**. [PMID: 40991619]**
[7] Hanson AL *et al. Nat Immunol*. 2024 **25**:471**. [PMID: 38429458]**
[8] Thangaleela S *et al. Sports Med Health Sci*. 2025 **8**:128. [PMID: 41737593]
[9] Chiriac OC *et al. Healthcare (Basel).* 2026 **14**:392. **[PMID: 41682242]**
[10] Bohmwald K *et al. Front Immunol*. 2024 **15**:1341600. **[PMID: 38482000]**
[11] Simón-Frapolli VJ *et al. Nutrients.* 2025 **17**:110. **[PMID: 39796549]**
[12] Bradbury J *et al. J Integr Complement Med*. 2023 **29**:695. **[PMID: 37102680]**
[13] Oliveira MR *et al. Arch Phys Med Rehabil*. 2024 **105**:1559. **[PMID: 38311096]**
[14] Saunders EG *et al. BMJ Public Health*. 2025 **3:**e001827**. [PMID: 40017924]**
[15] Perestiuk V *et al. Front Pediatr*. 2025 **13**:1507169**. [PMID: 40046855]**
[16] Gérard M *et al. Nutrients*. 2021 **13**:3964. [PMID: 34836219]
[17] Payne R *et al. Br J Gen Pract*. 2024 **74**:573. [PMID: 39609044]

Caveat Emptor is applicable among the literate community where required and possible. The publisher, its journal, editors and the internal/external reviewers take adequate steps to check, evaluate, correct, edit, revise and improve content where possible and required.