J Med Biosci Suppl 2025;7: S83 - S90 DOI: 10.58837/CHULA.JMBS.7.S1.13

Original article

Nutritional and inflammatory biomarker response to an egg white protein, nutritionally complete medical food *vs.* standard medical food in Hemodialysis: A randomized controlled trial

Siritorn Chobchuen[1], Sirakarn Tejavanija[2], Pichamon Namkieat[1], Suwimol Sapwarobol[1,*]

[1]Department of Nutrition and Dietetics, Faculty of Allied Health Sciences, Chulalongkorn University, Bangkok, Thailand
[2]Department of Medicine, Phramongkutklao Hospital, Bangkok, Thailand

Abstract

Background: Malnutrition is a common complication in hemodialysis (HD) patients, contributing to increased morbidity, mortality, and diminished quality of life. Medical foods offer a dietary strategy to improve nutritional status, especially when formulated with high-quality protein. Egg white protein is an excellent protein source, low in phosphorus, and appropriate for HD patients. However, limited clinical data exist regarding its impact on nutritional and inflammatory biomarkers in this population.

Objective: To compare the effects of a novel, egg white protein-based medical food (TEST) to a standard renal-specific medical food (CON) on biomarkers of nutritional status and inflammation in HD patients.

Methods: Sixty-six HD patients were randomized into two groups: the TEST (n = 34) received a novel egg white protein-based medical food, and the CON (n = 32) received a standard renal-specific medical food. Each group consumed one serving per day for 12 weeks. Nutritional biomarkers (albumin, prealbumin, total iron-binding capacity [TIBC]) and inflammatory marker (high-sensitivity C-reactive protein [hs-CRP]) were measured at baseline, week 6, and week 12.

Results: The TEST exhibited a significant increase in dry weight from baseline to week 12 (0.89 kg; 95% CI: 0.03–1.75; $P = 0.042$), while no significant change was observed in the CON. No significant differences were found between or within groups for albumin, prealbumin, TIBC, or hs-CRP during 12-week intervention.

Conclusion: An egg white protein-enriched medical food improved body weight and showed favorable trends in nutritional and inflammatory markers in HD patients. Further studies are needed to confirm these findings.

Keywords: Egg white protein, hemodialysis, inflammation, malnutrition, medical food.

*Correspondence to: Suwimol Sapwarobol, Department of Nutrition and Dietetics, Faculty of Allied Health Sciences, Chulalongkorn University, Bangkok 10330, Thailand.
Email. suwimol.sa@chula.ac.th.

End-stage renal disease (ESRD) is defined by a progressive and irreversible decline in renal function, with an estimated glomerular filtration rate (eGFR) below 15 mL/min/1.7 m², necessitating renal replacement therapy (RRT) for patient survival.[1] Hemodialysis (HD) and peritoneal dialysis (PD) are the primary modalities employed to maintain fluid and electrolyte balance and to eliminate metabolic waste products.

Among patients receiving HD, protein-energy wasting (PEW) represents a major clinical concern. PEW is characterized by the loss of body protein and energy stores, and is associated with poor nutritional status. Epidemiological studies estimate that over 50.0% of HD patients exhibit features of PEW, which is independently linked to increased rates of morbidity, mortality, and reduced quality of life (QoL).[2, 3]

The etiology of malnutrition in HD is multifactorial and closely associated with chronic systemic inflammation. Inflammation promotes protein catabolism, inhibits protein synthesis, and exacerbates nutritional deficits, further compromising clinical outcomes.[4] Biomarkers such as serum albumin and prealbumin are widely used to assess nutritional status, while total iron-binding capacity (TIBC) and high-sensitivity C-reactive protein (hs-CRP) serve as markers of inflammation. These biomarkers have been shown to correlate with malnutrition, inflammation, and QoL, and are predictive of hospitalization and mortality.[5]

Nutritional interventions, including medical foods, have demonstrated efficacy in improving nutritional markers in HD patients. Oral nutritional supplementation (ONS) has been associated with significant increases in serum albumin and prealbumin and reductions in hs-CRP. [6 - 8] Traditionally, whey protein has been the protein source of choice in medical foods due to its high biological value and rapid absorption.[9, 10] However, egg white protein has emerged as an alternative protein source due to its complete amino acid profile, low fat content, and suitability for patients with lactose intolerance or dairy allergies.[11]

Despite the theoretical benefits, data on the long-term effects of egg white protein-based medical foods on nutritional and inflammatory status in HD patients remain limited. Addressing this knowledge gap is essential to guide the development of targeted nutritional strategies aimed at improving clinical outcomes and quality of life in this high-risk population.

Therefore, this study aimed to compare the effects of a novel, nutritionally complete medical food enriched with egg white protein *vs.* a renal-specific medical food formula on biomarkers of nutritional status (serum prealbumin, albumin, and TIBC) and inflammation (hs-CRP) in patients undergoing hemodialysis.

Materials and methods

Study design

This 12-week, single-center, randomized controlled trial was conducted at Phramongkutklao Hospital, Bangkok, Thailand, from April 2024 to February 2025. The study aimed to compare the effects of a novel, nutritionally complete medical food enriched with egg white protein (TEST) to a standard renal-specific medical food (CON) on selected biochemical markers in patients undergoing HD. The study was approved by the Ethics in Human Research Committee of the Institutional Review Board, Royal Thai Army Medical Department (Approval no. RF 01_2563) and was registered with the Thai Clinical Trials Registry (TCTR20230613007). Written informed consent was obtained from all participants prior to enrollment.

A novel - high egg white protein, nutritionally complete medical food

The novel, nutritionally complete medical food, enriched with egg white protein (TEST) product was formulated with egg white protein powder, omega-3 oil powder, rice protein, rice bran oil creamer, Fibersol-2, Fibrulose F 97, Fibroline Instant, isomaltulose, maltodextrin DE 10–12, tapioca maltodextrin, sucrose, and vanilla malt flavor. Each 80 g serving provided 355 kcal, 19 g protein, 47 g carbohydrate, and 10 g fat, with low levels of sodium (191 mg), potassium (95 mg), phosphorus (39 mg), and magnesium (5 mg). Nutrient composition was verified by Asia medical and agricultural laboratory and research center.

The standard renal-specific formula medical food (CON) product contained whey protein isolate, casein, canola oil, high oleic safflower oil, rice bran oil, MCT oil, isomaltulose, Fibersol-2, fructooligosaccharide, and vanilla flavor. One 77 g serving provided 356 kcal, 16 g protein, 40 g carbohydrate, 16 g fat, and a mineral profile of sodium (149 mg), potassium (198 mg), phosphorus (144 mg), and magnesium (39 mg).

Study population

Participants were eligible if they were aged ≥ 20 years, had received maintenance HD at least twice weekly for a minimum of two months, and were able to adhere to the intervention protocol for 12 weeks. Exclusion criteria included: egg allergy; use of probiotics or phytonutrient-containing supplements; active infection or inflammation; significant gastrointestinal or hepatic disorders; immunodeficiency syndromes; dysphagia or aspiration risk; fluid overload; or consumption of medical food within one month prior to study enrollment.

Of 144 patients screened, 66 met inclusion criteria and were randomized in a 1:1 ratio to the TEST (n = 34) or CON (n = 32) groups using a computer-generated random number sequence. Both groups received one daily serving of their assigned medical food product, matched for energy and protein content. To rigorously evaluate the efficacy of the novel egg white protein-based medical food, a direct comparison with a standard renal-specific medical food currently used in clinical practice is essential. Such a comparative approach allows for the determination of whether the novel formulation achieves outcomes that are comparable or superior to those of the established product. Moreover, this design facilitates the assessment of the clinical utility of egg white protein as an alternative high-quality protein source, relative to traditional protein sources such as whey or casein, in improving nutritional and inflammatory biomarkers in patients undergoing hemodialysis.

Data collection tools

The primary outcomes included changes in serum albumin, prealbumin, total iron-binding capacity (TIBC), and high-sensitivity C-reactive protein (hs-CRP), measured at baseline, week 6, and week 12. Blood samples were collected and analyzed by certified medical technologists using standardized laboratory protocols. Dry weight and body mass index (BMI) were also assessed as secondary measures.

Participants were advised to maintain their usual dietary intake and physical activity throughout the study. Compliance was monitored via biweekly follow-up and review of consumption records.

Statistical analysis

Baseline characteristics of the intervention (TEST) and control (CON) groups were summarized using mean ± standard deviation (SD) or median and range (minimum, maximum) for continuous variables, and frequency with percentage for categorical variables. Between-group comparisons at baseline were conducted using independent *t*-tests or Mann-Whitney U tests for continuous variables, and Chi-square tests for categorical variables. Longitudinal changes in the primary outcome measures, serum albumin, prealbumin, TIBC, and hs-CRP across baseline, week 6, and week 12 were analyzed using the Generalized Estimating Equations (GEE) approach. This method accounted for intra-individual correlations by applying an exchangeable working correlation structure with robust standard errors. The statistical model included main effects for group (TEST vs. CON), time, and a group-by-time interaction term to evaluate the intervention effect over time. Baseline values of each outcome variable were included as covariates to adjust for any initial group differences. All statistical analyses were conducted using Stata version 18 (StataCorp, College Station, TX, USA), and a two-sided $P < 0.05$ was considered statistically significant.

Results

Baseline Characteristics

A total of 47 HD patients with end-stage renal disease (eGFR <15 mL/min/1.73 m²) completed the 12-week intervention, including 24 participants in the intervention group (TEST) and 23 in the control group (CON). The mean age was 56.8 ± 13.7 years in the TEST group and 52.5 ± 13.3 years in the CON group. Both groups were predominantly male, with male representation of 66.7% and 69.6% in the TEST and CON groups, respectively. The duration of HD ranged from 9.0 to 33.0 months in the TEST group and 6.0 to 24.0 months in the CON group. Most participants received HD three times per week (TEST: 75.0%; CON: 73.9%). Baseline characteristics were comparable between the two groups, with the exception of body mass index (BMI), which was significantly higher in the TEST group ($P = 0.039$), as summarized in **Table 1**.

Anthropometric and biochemical indicators

Baseline body weight did not differ significantly between groups and remained statistically comparable at weeks 6 and 12. Within-group analysis revealed no significant change in body weight in the TEST group across the 12-week period. However, a significant increase in body weight was observed in the CON group from baseline to week 6 (95% CI: 0.95 [0.02, 1.87], $P = 0.044$).

Table 1. Baseline characteristics.

Characteristics	TEST (n = 24)	CON (n = 23)	*P*-value
Age (year), mean ± SD	56.8 ± 13.7	52.5 ± 13.3	0.285
Gender, n (%)			0.831
Male	16 (66.7)	16 (69.6)	
Female	8 (33.3)	7 (30.4)	
Duration of HD, median (min, max)	13.5 (9.0, 33.0)	18.0 (6.0, 24.0)	0.610
Frequency of HD, n (%)			0.577
2 times a week	5 (20.8)	6 (26.1)	
3 times a week	18 (75.0)	17 (73.9)	
4 times a week	1 (4.2)	0 (0.0)	
Body weight, kg, mean ± SD	71.2 ± 18.2	65.2 ± 16.0	0.238
Dry weight, kg, mean ± SD	69.7 ± 17.1	64.3 ± 16.1	0.275
Body height, cm, mean ± SD	162.9 ± 8.3	165.3 ± 8.5	0.326
BMI, kg/m^2, mean ± SD	26.0 ± 5.3	23.2 ± 4.1	0.039*

Table 2. The changes in parameters at baseline, 6 and 12-week.

	TEST (n = 24)	CON (n = 23)	Mean difference[1]	*P*-value[1]
Body weight (kg)				
Baseline	71.2 ± 18.2	65.2 ± 16.0	6.0 (- 3.7, 15.7)[2]	0.225[2]
Week 6	71.6 ± 18.4	66.1 ± 16.7	- 0.6 (- 1.6, 0.5)	0.322
Week 12	71.8 ± 18.1	66.2 ± 17.4	- 0.4 (- 2.1, 1.3)	0.631
Change from 0 to 6	0.47 (- 0.1, 1.1)	0.95 (0.0, 1.9)	- 0.5 (- 1.6, 0.6)	0.398
Change from 0 to 12	0.65 (- 0.3, 1.6)	0.99 (- 0.4, 2.4)	- 0.3 (- 2.0, 1.3)	0.693
Change from 6 to 12	0.18 (- 0.5, 0.8)	0.04 (- 0.8, 0.9)	0.1 (- 0.9, 1.2)	0.799
P -value within group				
(0 *vs* 6), (0 *vs* 12), (6 *vs* 12)	0.132, 0.168, 0.584	0.044*, 0.166, 0.920		
P -value time (0 *vs* 6 *vs* 12)	0.294	0.123		
Dry weight (kg)				
Baseline	69.7 ± 17.1	64.3 ± 16.1	5.4 (- 4.0, 14.8)[2]	0.264[2]
Week 6	70.0 ± 17.6	64.6 ± 16.5	- 0.0 (- 0.9, 0.9)	0.934
Week 12	70.5 ± 17.6	65.0 ± 16.4	0.2 (- 1.2, 1.5)	0.799
Change from 0 to 6	0.4 (- 0.2, 0.9)	0.4 (- 0.4, 1.1)	0.0 (- 0.9, 0.9)	0.960
Change from 0 to 12	0.9 (0.0, 1.8)	0.7 (- 0.4, 1.7)	0.2 (- 1.1, 1.6)	0.727
Change from 6 to 12	0.5 (- 0.2, 1.3)	0.3 (- 0.2, 0.8)	0.2 (- 0.7, 1.1)	0.632
P -value within group				
(0 *vs*. 6), (0 *vs.* 12), (6 *vs.* 12)	0.204, 0.042**, 0.162	0.334, 0.209, 0.213		
P -value time (0 *vs.* 6 *vs.* 12)	0.123	0.418		
BMI (kg/m^2)				
Baseline	26.0 ± 5.3	23.2 ± 4.1	2.8 (0.1, 5.5)[2]	0.039[2]
Week 6	26.2 ± 5.5	23.4 ± 4.3	- 0.01 (- 0.3, 0.3)	0.942
Week 12	26.4 ± 5.4	23.5 ± 4.2	0.03 (- 0.5, 0.5)	0.905
Change from 0 to 6	0.16 (- 0.1, 0.4)	0.13 (- 0.1, 0.4)	0.03 (- 0.3, 0.4)	0.843
Change from 0 to 12	0.32 (0.0, 0.6)	0.25 (- 0.1, 0.6)	0.08 (- 0.4, 0.6)	0.753
Change from 6 to 12	0.16 (- 0.1, 0.4)	0.12 (- 0.1, 0.3)	0.04 (- 0.3, 0.3)	0.784
P -value within group				
(0 *vs.* 6), (0 *vs.* 12), (6 *vs.* 12)	0.157, 0.043**, 0.204	0.329, 0.177, 0.162		
P -value time (0 *vs*. 6 *vs.* 12)	0.125	0.343		
eGFR (ml/min/1.73m^2)				
Baseline	6.2 ± 1.8	6.5 ± 2.3	- 0.3 (- 1.5, 0.9)[2]	0.630[2]
Week 6	6.6 ± 2.3	6.6 ± 2.3	0.2 (- 0.6, 1.1)	0.607
Week 12	6.6 ± 1.8	7.6 ± 3.6	- 0.7 (- 2.2, 0.7)	0.314
Change from 0 to 6	0.4 (- 0.2, 1.0)	0.1 (- 0.6, 0.8)	0.3 (- 0.6, 1.2)	0.545
Change from 0 to 12	0.4 (- 0.3, 1.2)	1.12 (- 0.2, 2.4)	- 0.7 (- 2.2, 0.8)	0.358
Change from 6 to 12	0.1 (- 0.5, 0.6)	1.01 (- 0.3, 2.3)	- 1.0 (- 2.4, 0.5)	0.183

Table 2. (Cont.) The changes in parameters at baseline, 6 and 12-week.

	TEST (n = 24)	CON (n = 23)	Mean difference[1]	*P* -value[1]
P -value within group				
(0 *vs.* 6), (0 *vs.* 12), (6 *vs.* 12)	0.195, 0.269, 0.854	0.773, 0.083, 0.129		
P -value time (0 *vs.* 6 *vs.* 12)	0.410	0.222		
Serum albumin (g/dL)				
Baseline	4.3 ± 0.4	4.4 ± 0.31	- 0.01 (- 0.2, 0.18)[2]	0.897[2]
Week 6	4.3 ± 0.4	4.4 ± 0.28	- 0.14 (- 0.26, - 0.01)	0.038
Week 12	4.4 ± 0.4	4.4 ± 0.3	- 0.03 (- 0.17, 0.11)	0.706
Change from 0 to 6	- 0.04 (- 0.2, 0.1)	0.09 (0.01, 0.18)	- 0.13 (- 0.27, 0)	0.051
Change from 0 to 12	0.04 (- 0.1, 0.2)	0.07 (- 0.02, 0.16)	- 0.02 (- 0.17, 0.12)	0.739
Change from 6 to 12	0.09 (- 0.1, 0.2)	- 0.02 (- 0.13, 0.09)	0.11 (- 0.07, 0.29)	0.230
p -value within group				
(0 *vs.* 6), (0 *vs.* 12), (6 *vs.* 12)	0.423, 0.449, 0.223	0.037*, 0.143, 0.709		
P time (0 *vs.* 6 *vs.* 12)	0.474	0.067		
Prealbumin (mg/dL)				
Baseline	36.4 ± 8.2	35.2 ± 4.9	1.3 (- 2.3, 5.0)[2]	0.479[2]
Week 6	37.1 ± 8.9	35.2 ± 5.4	0.4 (-2.4, 3.2)	0.786
Week 12	36.4 ± 8.5	35.4 ± 5.3	-0.4 (-3.6, 2.7)	0.781
Change from 0 to 6	0.5 (- 1.9, 2.8)	0.2 (- 1.4, 1.8)	0.3 (-2.5, 3.1)	0.826
Change from 0 to 12	0.1 (- 2.6, 2.7)	0.4 (- 1.2, 1.9)	-0.5 (-3.7, 2.6)	0.746
Change from 6 to 12	- 0.4 (- 2.3, 1.5)	0.2 (- 1.1, 1.5)	-0.8 (-3.4, 1.7)	0.524
P -value within group				
(0 *vs.* 6), (0 *vs.* 12), (6 *vs.* 12)	0.704, 0.960, 0.695	0.825, 0.651, 0.792		
P - value time (0 *vs.* 6 *vs.* 12)	0.885	0.898		
TIBC (ug/dL)				
Baseline	215.3 ± 39.8	200.0 ± 46.5	15.3 (- 9.2, 39.9)[2]	0.220[2]
Week 6	213.9 ± 41.7	207.6 ± 50.4	- 8.0 (- 18.8, 2.8)	0.145
Week 12	214.3 ± 44.5	205.3 ± 41.9	- 5.4 (- 18.8, 8.1)	0.436
Change from 0 to 6	- 1.4 (- 9.2, 6.4)	7.61 (- 0.1, 15.3)	- 9.0 (- 19.9, 1.8)	0.103
Change from 0 to 12	- 1.0 (- 12.0, 9.9)	5.3 (- 3.9, 14.5)	- 6.4 (- 20.5, 7.8)	0.379
Change from 6 to 12	0.4 (- 8.6, 9.4)	-2.3 (-10.7, 6.1)	2.7 (- 9.5, 14.9)	0.666
P -value within group				
(0 *vs.* 6), (0 *vs.* 12), (6 *vs.* 12)	0.722, 0.852, 0.935	0.053, 0.259, 0.592		
P -value time (0 *vs* 6 *vs* 12)	0.939	0.151		
hs-CRP (mg/L)				
Baseline	6.7 ± 14.5	5.9 ± 9.5	0.3 (- 6.5, 7.2)[2]	0.921[2]
Week 6	6.2 ± 13.5	4.2 ± 8.6	1.5 (- 0.1, 3.1)	0.074
Week 12	4.1 ± 3.5	3.1 ± 3.4	2.3 (0.2, 4.5)	0.030
Change from 0 to 6	0.03 (- 1.0, 1.1)	- 1.5 (- 2.8, - 0.2)	1.4 (- 0.2, 3.1)	0.086
Change from 0 to 12	0.04 (- 2.4, 2.5)	-1 .3 (- 3.1, 0.5)	2.3 (0.1, 4.5)	0.038
Change from 6 to 12	0.01 (- 2.2, 2.2)	0.2 (-1.5, 1.8)	0.9 (- 1.4, 3.1)	0.452
P -value within group				
(0 *vs.* 6), (0 *vs.* 12), (6 *vs.* 12)	0.948, 0.972, 0.993	0.029*, 0.147, 0.856		
P -value time (0 *vs.* 6 *vs.* 12)	0.998	0.086		

Values were shown as mean ± SD or mean (95% CI). Body mass index (BMI); eGFR, Estimated glomerular filtration rate; TIBC, Total iron binding capacity; hs-CRP, High-sensitive C-reactive protein. [1] Based on the Generalized estimating equations (GEE) model, adjusted for the baseline score; [2] Based on the GEE model, unadjusted for the baseline score.

* *P* -value for a statistically significant difference between baseline and week 6 within group.

** *P* -value for a statistically significant difference between baseline and week 12 within group.

*** *P* -value for a statistically significant difference between week 6 and week 12 within group.

The TEST group exhibited a statistically significant increase in dry weight from baseline to week 12 (95% CI: 0.89 [0.03, 1.75], $P = 0.042$), whereas the CON group showed no significant change over the same period. No significant differences in dry weight were found between groups at any time points. At baseline, BMI was significantly higher in the TEST group (26.0 ± 5.3 kg/m²) than in the CON group (23.2 ± 4.1 kg/m²) ($P = 0.039$). No inter-group differences in BMI were observed at follow-up. Within the TEST group, BMI increased significantly from baseline to week 12 (95% CI: 0.32 [0.01, 0.64], $P = 0.043$), as shown in **Table 2**.

There were no statistically significant changes in eGFR, serum prealbumin, or TIBC between or within groups throughout the 12-week intervention ($P > 0.05$). Serum albumin levels remained stable in the TEST group. In contrast, the CON group showed a significant increase in serum albumin from baseline (4.35 ± 0.31 g/dL) to week 6 (4.4 ± 0.3 g/dL) (95% CI: 0.09 [0.01, 0.18], $P = 0.037$); however, this effect did not persist at week 12 ($P > 0.05$). High-sensitivity C-reactive protein (hs-CRP) levels in the TEST group did not significantly change over time. In contrast, the CON group demonstrated a significant reduction in hs-CRP from baseline (5.9 ± 9.5 mg/L) to week 6 (4.2 ± 8.6 mg/L) (95% CI: -1.48 [-2.81, -0.15], $P = 0.029$). At week 12, a significant between-group difference in hs-CRP was observed (95% CI: 2.34 [0.22, 4.46], $P = 0.030$). Additionally, the change in hs-CRP from baseline to week 12 showed a statistically significant difference between groups (95% CI: 2.31 [0.13, 4.48], $P = 0.038$) in **Table 2**.

Discussion

This 12-week randomized controlled trial aimed to evaluate the effects of a novel egg white protein-enriched medical food (TEST) compared to a renal-specific formula (CON) on biomarkers of nutritional status (serum prealbumin, albumin, TIBC) and inflammation (hs-CRP) in HD patients. Our findings indicate that the TEST group demonstrated statistically significant improvements in dry weight and BMI, while the CON group showed trends towards changes that did not reach statistical significance. These results suggest that the novel egg white protein-enriched medical food has a beneficial effect on anthropometric measures, particularly in HD patients who are often at risk of malnutrition. Prior studies have similarly reported improvements in body weight, dry weight, and BMI after medical food interventions of at least one month[6, 7, 12], reinforcing the potential positive impact of medical foods in managing malnutrition in chronic kidney disease (CKD).

Serum albumin and prealbumin, both key indicators of nutritional status, are closely associated with health outcomes in HD patients.[13, 14] Prior randomized controlled trials have demonstrated that malnourished HD patients receiving ONS experienced significant increases in serum albumin and prealbumin levels. Limwannata P, *et al.* [15] observed improvements in these biomarkers following daily consumption of ONCE Dialyze® (370 kcal, 17.0 g protein).[7] Similarly, non-randomized trials have reported statistically significant increases in serum albumin after six months of renal-specific ONS supplementation (28-42 g protein, 800-1,200 kcal/day) in malnourished HD patients. These findings underscore the potential of ONS in improving nutritional markers and addressing malnutrition in HD patients, suggesting that tailored nutritional interventions can have a significant impact on the management of nutritional deficiencies commonly observed in this population. Our study, however, did not find significant changes in these biomarkers in either the TEST or CON groups, despite baseline serum albumin levels being within the normal range. This discrepancy could be explained by the inclusion of patients with relatively normal nutritional status at baseline. Similar findings were observed in other trials with non-malnourished patients, where ONS did not significantly alter serum albumin or prealbumin levels. This suggests that the baseline nutritional status of the participants may play a crucial role in determining the efficacy of the intervention.

Furthermore, Caglar K, *et al.* [6] reported significant increases in both serum albumin and prealbumin levels following a six-month intervention with Nepro® (475 kcal, 16.6 g protein) in malnourished HD patients. In contrast, the current trial did not observe statistically significant changes in serum albumin or prealbumin levels in either group over the 12-week intervention period. This discrepancy may stem from differences in baseline nutritional status, as participants in the present study were not classified as malnourished and exhibited serum albumin concentrations within the normal reference range (3.5–5.5 g/dL). Supporting these findings, previous studies have similarly reported no significant alterations in serum albumin or prealbumin levels following six months of ONS during dialysis sessions,

even when the supplements provided up to 31 g of protein per serving.[16] Additionally, Fouque D, *et al.* [12] observed no significant changes in these nutritional biomarkers in maintenance HD patients receiving a renal-specific ONS containing 19 g of protein over a 12-week period. Collectively, these consistent observations suggest that the absence of significant changes in serum albumin and prealbumin may be attributed to similarities in baseline patient characteristics, nutritional supplement formulations, protein content, and underlying comorbidities.

TIBC, an essential marker reflecting transferrin concentrations and overall iron-binding capacity, serves as an indirect indicator of both iron metabolism and nutritional status in hemodialysis patients.[5] In the current study, TIBC levels remained unchanged in the TEST group and did not differ significantly between groups throughout the 12-week intervention. These findings diverge from those of Gharib MS, *et al.* [17], who reported significant improvements in serum albumin, prealbumin, and TIBC, alongside reductions in hs-CRP, after administering a 3-month intradialytic ONS containing 423 kcal and 26 g of protein to malnourished HD patients. However, the present findings are consistent with other investigations that observed no significant alterations in transferrin levels following six months of intradialytic ONS, even with similar or higher protein content.[6] The discrepancies among studies may be attributed to variations in the nutritional status of participants at baseline, with malnourished individuals potentially demonstrating greater responsiveness to ONS interventions. Additionally, differences in the energy and protein composition of the supplements, the duration of intervention, and the presence of comorbid conditions may all play critical roles in determining the responsiveness of TIBC to nutritional therapy.

hs-CRP, a sensitive and widely recognized biomarker of systemic inflammation associated with cardiovascular morbidity and metabolic disturbances in HD patients [18], did not exhibit statistically significant changes in the TEST group over the 12-week intervention. This result aligns with findings from earlier studies, such as those by Satirapoj B, *et al.* [19] which demonstrated no significant changes in hs-CRP or serum albumin levels following a 15-day intervention with a renal-specific nutritional formula. Similarly, Sezer S, *et al.* [15] reported stable hs-CRP concentrations after six months of supplementation with a high-protein, energy-dense nutritional formula in malnourished HD patients, suggesting that certain formulations or intervention durations may have limited anti-inflammatory effects.

Conversely, the CON group in the present study exhibited a statistically significant reduction in hs-CRP from baseline to week 6, although this effect was not sustained through week 12. Nevertheless, both groups demonstrated a downward trend in hs-CRP levels at the study's conclusion, which may indicate potential anti-inflammatory benefits from the interventions. This pattern is in line with prior studies indicating that medical nutrition products enriched with bioactive compounds, such as omega-3 fatty acids, antioxidants, or specific amino acids, may contribute to modulation of inflammatory pathways.[20] Therefore, while the absence of statistically significant reductions in hs-CRP in the TEST group may reflect the supplement's composition or the relatively short intervention period, the observed trends support the hypothesis that targeted nutritional interventions can play a role in mitigating inflammation in HD populations.

Conclusion

This 12-week intervention demonstrated that the novel egg white protein-enriched medical food resulted in significant improvements in dry weight and BMI in HD patients. While no significant changes were observed in serum albumin, prealbumin, TIBC, or hs-CRP, trends indicating potential improvements in these biomarkers were observed. These findings suggest that egg white protein could be a viable alternative protein source for medical foods in HD patients, particularly in enhancing anthropometric measures. However, the lack of significant changes in certain biomarkers may be attributed to the non-malnourished status of the participants. Future studies with larger sample sizes, longer follow-up periods, and comprehensive monitoring of dietary intake are needed to better understand the long-term effects of egg white protein-based medical foods on nutritional and inflammatory biomarkers in HD patients. Furthermore, incorporating a broader range of biomarkers and assessing overall quality of life would provide valuable insights into the full potential of this novel intervention.

Acknowledgements

The authors gratefully acknowledge the financial support provided by the National Research Council of Thailand (N23H660041) and the 90th Anniversary Chulalongkorn University Fund

(Ratchadaphiseksomphot Endowment Fund), which enabled the completion of this study. Special thanks are extended to the dedicated medical and dietetic team at Phramongkutklao Hospital for their invaluable contributions to data collection. Most importantly, we express our sincere gratitude to the patients who diligently and enthusiastically participated in this study.

Conflict of interest

The authors declare no conflict of interest.

Data sharing statement

All data generated or analyzed during the present study are included in this published article. The corresponding author's details are available for noncommercial purposes on reasonable request.

References

1. Wouk N. End-stage renal disease: Medical management. Am Fam Physician 2021;104:493-9.
2. Al Wakeel J, Al Harbi A, Bayoumi M, Al-Suwaida K, Al Ghonaim M, Mishkiry A. Quality of life in hemodialysis and peritoneal dialysis patients in Saudi Arabia. Ann Saudi Med 2012;32:570-4.
3. Zazzeroni L, Pasquinelli G, Nanni E, Cremonini V, Rubbi I. Comparison of quality of life in patients undergoing hemodialysis and peritoneal dialysis: A systematic review and meta-analysis. Kidney Blood Press Res 2017;42:717-27.
4. Sahathevan S, Khor BH, Ng HM, Gafor AHA, Mat Daud ZA, Mafra D, et al. Understanding Development of Malnutrition in Hemodialysis Patients: A Narrative Review. Nutrients 2020;12:3147.
5. Bross R, Zitterkoph J, Pithia J, Benner D, Rambod M, Kovesdy CP, et al. Association of serum total iron-binding capacity and its changes over time with nutritional and clinical outcomes in hemodialysis patients. Am J Nephrol 2009;29:571-81.
6. Caglar K, Fedje L, Dimmitt R, Hakim RM, Shyr Y, Ikizler TA. Therapeutic effects of oral nutritional supplementation during hemodialysis. Kidney Int 2002;62:1054-9.
7. Limwannata P, Satirapoj B, Chotsriluecha S, Thimachai P, Supasyndh O. Effectiveness of renal-specific oral nutritional supplements compared with diet counseling in malnourished hemodialysis patients. Int Urol Nephrol 2021;53:1675-87.
8. Liu PJ, Guo J, Zhang Y, Wang F, Yu K. Effects of oral nutritional supplements on the nutritional status and inflammatory markers in patients on maintenance dialysis: a systematic review and meta-analysis of randomized clinical trials. Clinical Kidney J 2023;16:2271-88.
9. Arentson-Lantz EJ, Kilroe S. Practical applications of whey protein in supporting skeletal muscle maintenance, recovery, and reconditioning. J Anim Sci 2021;99:skab060.
10. Davies RW, Carson BP, Jakeman PM. The effect of whey protein supplementation on the temporal recovery of muscle function following resistance training: A systematic review and meta-analysis. Nutrients 2018;10:221.
11. Guida B, Parolisi S, Coco M, Ruoppo T, Veccia R, di Maro M, et al. The impact of a nutritional intervention based on egg white for phosphorus control in hemodialyis patients. Nutr Metab Cardiovasc Dis 2019;29:45-50.
12. Fouque D, McKenzie J, de Mutsert R, Azar R, Teta D, Plauth M, et al. Use of a renal-specific oral supplement by haemodialysis patients with low protein intake does not increase the need for phosphate binders and may prevent a decline in nutritional status and quality of life. Nephrol Dial Transplant 2008;23:2902-10.
13. Sabatino A, Piotti G, Cosola C, Gandolfini I, Kooman JP, Fiaccadori E. Dietary protein and nutritional supplements in conventional hemodialysis. Semin Dial 2018;31:583-91.
14. Liu PJ, Ma F, Wang QY, He SL. The effects of oral nutritional supplements in patients with maintenance dialysis therapy: A systematic review and meta-analysis of randomized clinical trials. PLoS One 2018;13: e0203706.
15. Sezer S, Bal Z, Tutal E, Uyar ME, Acar NO. Long-term oral nutrition supplementation improves outcomes in malnourished patients with chronic kidney disease on hemodialysis. JPEN J Parenter Enteral Nutr 2014;38: 960-5.
16. Caetano C, Valente A, Silva FJ, Antunes J, Garagarza C. Effect of an intradialytic protein-rich meal intake in nutritional and body composition parameters on hemodialysis patients. Clin Nutr ESPEN 2017;20:29-33.
17. Gharib MS, Nazeih MS, El Said TW. Effect of intradialytic oral nutritional supplementation on nutritional markers in malnourished chronic hemodialysis patients: prospective randomized trial. BMC Nephrol 2023;24:125.
18. Heidari B. C-reactive protein and other markers of inflammation in hemodialysis patients. Caspian J Intern Med 2013;4:611-6.
19. Satirapoj B, Limwannata P, Kleebchaiyaphum C, Prapakorn J, Yatinan U, Chotsriluecha S, et al. Nutritional status among peritoneal dialysis patients after oral supplement with ONCE dialyze formula. Int J Nephrol Renovasc Dis 2017;10:145-51.
20. Gharekhani A, Khatami MR, Dashti-Khavidaki S, Razeghi E, Abdollahi A, Hashemi-Nazari SS, et al. Effects of oral supplementation with omega-3 fatty acids on nutritional state and inflammatory markers in maintenance hemodialysis patients. J Ren Nutr 2014;24:177-85.