# Intradialytic Exercise Protocol in Patients with Chronic Kidney Disease: A Single Center Experience

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## Abstract

**Introduction:** Chronic kidney disease (CKD) requires life-sustaining therapies such as hemodialysis (HD), which negatively affects patients' quality of life. Physical exercise has emerged as a promising, non-pharmacological strategy to mitigate these adverse effects.

**Methods:** This clinical study, conducted in Guarapuava, Brazil, included 41 HD patients who were divided into an intervention group (IG, n=28) and a control group (CG, n=13). Assessments were performed at baseline and after an eight-week intradialytic physical exercise program. The intervention consisted of stretching, resistance training (quadriceps, hip abductors/adductors, and ankle musculature), and aerobic activity (using a cycle ergometer). Exercises were individualized and monitored by measuring vital signs and applying the Borg Rating of Perceived Exertion Scale.

**Results:** Forty-one participants (28 IG, 13 CG) completed the protocol. The mean age was 56.5±10.22 years, with hypertension and diabetes mellitus (DM) as the most prevalent comorbidities. Participants with DM had higher body mass index (BMI) and significantly lower dialysis adequacy (Kt/V). After intervention, the IG showed significant improvements in dialysis adequacy (from 1.27 to 1.42; *p*=0.004), handgrip strength (*p*=0.001), and Barthel Index scores (*p*=0.0021), reflecting greater independence in activities of daily living. Multivariate analysis (MANOVA) and Hedges' g indicated moderate to large effect sizes, supporting the clinical relevance of these gains.

**Conclusion:** The findings indicate that intradialytic physical exercise yields clinically meaningful functional and physiological improvements, reinforcing its relevance as an effective adjunct to routine care for CKD patients undergoing hemodialysis.

**Keywords:** Exercise; Quality of Life; Renal Dialysis; Renal Insufficiency, Chronic

## INTRODUCTION

Chronic kidney disease (CKD) is characterized by a progressive and irreversible decline in renal structure and function, leading to increased morbidity, mortality, and risk of complications, especially cardiovascular and metabolic.[1] Its etiology is multifactorial, with diabetes mellitus and systemic arterial hypertension as the main causes, while glomerulopathies, autoimmune diseases, and hereditary conditions also contribute significantly.[2] As CKD progresses, the kidneys lose the ability to perform essential physiological functions, clinically manifesting as fatigue, edema, hypertension, anemia, and progressive loss of lean muscle mass.[3]

Hemodialysis (HD) is a renal replacement therapy used in patients with severe renal insufficiency, promoting partial restoration of fluid, electrolyte, and metabolic balance through blood filtration in a dialyzer, based on diffusion and ultrafiltration processes.[4] Although it alleviates uremic symptoms and increases survival in the terminal phase of CKD, HD does not completely reverse metabolic and inflammatory changes and may worsen the catabolic state.[5] Sarcopenia is a frequent complication in CKD, especially in patients on HD, characterized by the loss of muscle mass and strength and worsening physical performance, aggravated by aging.[6] Its progression is related to physical

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inactivity, chronic inflammation, malnutrition, and hormonal alterations,[7] involving mechanisms such as insulin resistance, reduction of the IGF-1/AKT/mTOR axis, and increased protein catabolism induced by dialysis,[8] with a negative impact on autonomy, quality of life, and higher hospitalization rates.[9]

In CKD, the loss of muscle mass and function is closely related to a persistent catabolic state, characterized by increased protein degradation and reduced muscle synthesis.[10] This catabolism is potentiated by chronic systemic inflammation, which activates intracellular pathways associated with proteolysis, including the ubiquitin-proteasome system.[11] At the same time, increased oxidative stress, resulting from the accumulation of uremic toxins and mitochondrial dysfunction, leads to excessive production of reactive oxygen species, contributing to cellular damage, muscle fiber apoptosis, and worsening sarcopenia in this population.[12]

CKD is associated with a progressive impairment of health-related quality of life, significantly affecting physical, psychological, and social domains. Evidence shows that CKD patients have reduced physical functioning, greater fatigue, pain, and limitations in daily activities, as well as increased depressive symptoms and poorer emotional well-being, with proportional worsening as the disease progresses and dialysis stages advance.[13,14] Additionally, the high burden of treatment, including the demands of dialysis therapy and restrictions imposed by the disease, contributes to worse perceived quality of life throughout the clinical course of CKD.[15,16]

In the Brazilian context, CKD represents a major public health problem, characterized by the significant growth of the population undergoing renal replacement therapy and the predominance of hemodialysis as the main modality. Epidemiological studies show a sustained increase in disease prevalence, strong dependence on the public health system, and regional inequalities in access to treatment—factors that directly impact clinical outcomes and patients' quality of life.[17] This scenario reinforces the need for strategies focused on prevention, early detection, and optimization of care, with an emphasis on reducing the functional, psychosocial, and economic impact of CKD.[16]

In this context, regular physical exercise and a healthy lifestyle are essential to mitigate the progression of sarcopenia and its associated consequences. Physical activity is a well-established non-pharmacological intervention that promotes improvements in physical, mental, and emotional health, contributing to overall enhancement of quality of life.[18] Among individuals with CKD, exercise can confer additional benefits, including attenuation of renal function decline, improvements in functional capacity, and reduction of cardiovascular risk,[19] as well as favoring the preservation of muscle mass and improvement of dialysis adequacy. Structured exercise protocols, especially supervised intradialytic resistance exercise, have been proposed as a viable strategy to stimulate muscle protein synthesis during HD sessions.[20]

Given the high clinical burden of CKD, including high treatment costs, elevated mortality, and a profound impact on daily life and public health, as well as the heterogeneity in the literature regarding the ideal type, intensity, and duration of intradialytic exercise protocols, the present study aimed to evaluate whether an intradialytic exercise protocol could promote functional and physiological improvements in hemodialysis patients. Additionally, the study sought to examine its potential to attenuate sarcopenia, improve quality of life, and optimize relevant clinical outcomes.

## METHODOLOGY

This study was designed as a feasibility clinical trial conducted in a clinically vulnerable population. This clinical trial was approved by the Research Ethics Committee of the State University of the Central-West (Universidade Estadual do Centro-Oeste - UNICENTRO), under approval no. 6.155.504. All evaluations were conducted at the Renal Disease Clinic (Clínica de Doenças Renais – CLIRE), located in Guarapuava, Paraná, Brazil, between August and December 2023.

The study included patients from the Brazilian Unified Health System (Sistema Único de Saúde – SUS), a public, universal health system, who were referred for treatment at the CLIRE clinic. A physiotherapeutic intradialytic exercise protocol was implemented in CKD patients undergoing HD through an arteriovenous fistula to assess its effect on fall risk, peripheral muscle strength, physical activity levels, QoL, and dialysis adequacy.

Artificial intelligence–based tools were used solely to assist in language editing and text refinement. The authors maintained full responsibility for the study design, data analysis, interpretation of findings, and final content of the manuscript. No AI tools were used for data generation, analysis, or scientific decision-making.

### Eligibility Framework, Regional Profile, and Sample Size Methodology

Individuals over 18 years of age with a clinical diagnosis of CKD, undergoing hemodialysis via arteriovenous fistula, able to perform the exercise protocol, and who signed the free and informed consent form (*termo de consentimento livre e esclarecido* – TCLE) were included. Exclusion criteria comprised recent lower-limb surgeries or recent arteriovenous fistula, limb amputations, age under 18 years, and any physical or cognitive impairments that could compromise understanding or execution of the study procedures, as well as failure to meet the inclusion criteria.

Fig. 1 presents the flowchart of participant selection. Of the 210 individuals initially assessed, 41 met the eligibility criteria and were included in the final analysis, with allocation into a control group of 13 participants and an intervention group of 28 participants.

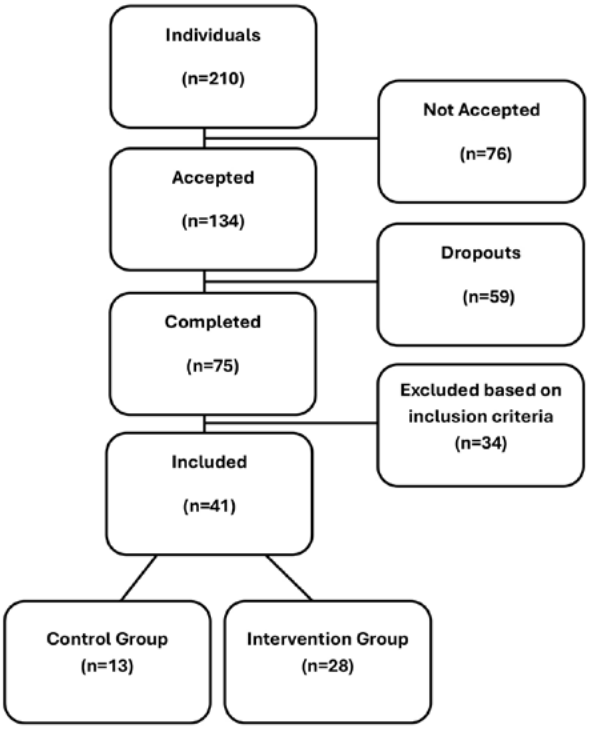


Figure 1. Flowchart of the study participant selection process, from recruitment to completion of the protocol.

Located in the south-central region of Paraná, Brazil, the 5th Regional Health Department is characterized by low socioeconomic indicators. It consists mainly of small municipalities whose economies are predominantly based on rural agriculture and regional industries. This context poses challenges for healthcare provision and service logistics, particularly regarding accessibility and continuity of care, which adversely affect the management of chronic conditions, such as those requiring renal replacement therapy.[21]

The demographic reference was based on municipal Brazilian Institute of Geography and Statistics (IBGE) data, while the accessible clinical population comprised 210 patients undergoing hemodialysis at the clinic CLIRE. A sample size calculation with 95% confidence (Z= 1.96) and a conservative proportion ($p$= 0.5) indicated a corrected sample of 130 participants for a 5% margin of error. However, only 41 individuals met the strict eligibility criteria, which accounted for the restricted service flow and the follow-up losses commonly seen in clinical studies involving CKD patients undergoing hemodialysis.[22] To reduce bias and maintain methodological rigor, robust statistical analyses, effect size measurement, and achieved power verification were applied, adopting $p$< 0.05 as the threshold for significance.

$$n = \frac{n_0}{1 + \frac{n_0 - 1}{N}}$$

Equation 1. Sample size calculation based on Cochran's method (1977).[23]

The sample size parameters included N (total eligible population), $n_0$ (initial sample without population correlation), Z (critical value for the chosen confidence level), $p$ (estimated proportion or expected variability), and d (acceptable margin of error).

## Instruments

Data collection was conducted using questionnaires developed in Google Forms. Evaluations included clinical and sociodemographic data, such as personal information, clinical diagnosis, anthropometric measurements, vital signs, lifestyle habits, education, social factors, and treatment-related information.

Physical and functional assessments included the following instruments: SARC-F for sarcopenia screening (muscle strength, mobility, lower limb function, fall history)[24]; Fatigue Severity Scale (FSS) for fatigue assessment[25]; Medical Research Council (MRC) Scale for muscle strength evaluation[26]; Five Time Sit-to-Stand Test (FTSTS) for lower limb strength and power[27]; Barthel Index to assess independence in activities of daily living[28]; International Physical Activity Questionnaire (IPAQ) for physical activity levels classification[29]; Circumference measurements of the upper limbs (UL), lower limbs (LL), and abdominal circumference (AC)[30]; Handgrip Strength (HGS), measured with a hand dynamometer[31]; Kidney Disease Quality of Life Short Form (KDQoL™ 1.3) for quality of life assessment[32]; Dialysis adequacy (Kt/V) (K = urea clearance; t = dialysis time; V = urea distribution volume).[33]

### Physiotherapeutic Exercise Protocol

Participants underwent a physiotherapeutic treatment protocol during HD sessions over eight weeks. Each protocol was individualized according to the patient's functional and physical capacity. Exercises were supervised by the physiotherapist (ensuring safety, effectiveness, and adherence) and performed during the first two hours of the HD session, within a total session duration of three to four hours, lasting approximately 50 minutes. The intervention consisted of three sets of 10 repetitions per exercise, based on Ferrarini's protocol.[34]

Exercise sessions were immediately interrupted if symptoms such as fatigue, dyspnea, angina, hypotension, pain, dizziness, nausea, or venous pressure exceeding 300 mmHg occurred. Vital signs were continuously monitored, and the Modified Borg Scale was used to assess perceived dyspnea and lower-limb fatigue, ranging from 0 (no symptoms) to 10 (maximum fatigue).[35] Following Ferrarini,[34] the protocol involved comprehensive lower-limb training targeting the hip abductors (gluteus medius, gluteus maximus, and tensor fasciae latae), adductors (adductor longus, adductor brevis, adductor magnus, gracilis, and pectineus), hamstrings (semitendinosus, semimembranosus, and biceps femoris), and quadriceps (rectus femoris, vastus medialis, vastus lateralis, and vastus intermedius). Sessions began with self-stretching of the hip adductors and abductors, followed by the quadriceps and ankle musculature. Aerobic exercise was performed on a cycle ergometer while patients remained seated in the dialysis chair during HD. Load and cadence were individualized based on fatigue levels, with adjustments made as needed. If aerobic activity was interrupted prematurely, the rest period was recorded, and the timer continued until the prescribed 20 minutes were completed.

### Scientometric Analysis

A scientometric analysis was conducted to quantitatively and qualitatively examine the scientific literature output on physical exercise in CKD patients undergoing HD. Searches were performed in Web of Science, PubMed, and SciELO databases, using the descriptors (hemodialysis OR intradialysis AND chronic kidney disease OR chronic kidney failure AND physical exercise OR physical activity). Inclusion criteria were: primary quantitative studies published between 2010 and 2024, in English, Portuguese, or Spanish, involving HD patients with CKD and addressing the effect of physical exercise on health and QoL. Reviews, experience reports, and letters to the editor were excluded.

Data were analyzed using VOSviewer software, which identifies term occurrence frequencies, thematic clusters, and the temporal evolution of the research field. The terms' relevance was calculated based on their frequency and context, contributing to a broader understanding of the trends and impact on scientific output in this field.

### Statistical Analysis

Data were expressed as mean ± standard deviation or as absolute frequencies. Normality was assessed using the Shapiro-Wilk test. Categorical variables were analyzed using the chi-square test, and paired t-tests were used to compare continuous variables before and after the intervention. Significance was set at $p < 0.05$. A multivariate analysis of variance (MANOVA) was used to examine the relationships among multiple independent variables and the outcomes of interest. Effect sizes were calculated using Hedges' $g$ to estimate the magnitude of observed differences. Statistical analyses were performed using RStudio.

## RESULTS

The clinical trial evaluated 41 patients with CKD undergoing HD, all residing within the jurisdiction of the 5th Regional Health Office of Paraná and treated at CLIRE. As shown in Table 1, 28 individuals agreed to participate in the intradialytic exercise protocol (intervention group, GI), while 13 declined (control group, CG). The population consisted of 48.78% men and 51.22% women. Anthropometric data revealed a mean age of 56.5±10.22 years, a mean weight of 68.2±14.6 kg, a height of 1.63±0.11 m, and a mean body mass index (BMI) of 25.4±4.99, indicating that approximately 53% of patients were overweight. Regarding sociodemographic characteristics, 51.22% had completed elementary education, and 56.1% reported a household income of one to three times the minimum Brazilian wage (BRL 1320.00- USD 245–250).

Physical activity assessed using the IPAQ (Table 1) showed that, at baseline, most patients had a sedentary or minimally active lifestyle: 24.39% were sedentary and 34.15% irregularly active. After intervention, a modest increase in self-reported physical activity was observed, with the proportion of highly active individuals rising (from 2.44% to 9.76%) and sedentary ones decreasing (from 19.51% to 12.20%), suggesting a positive impact of the protocol ($p$= 0,03).

Table 1. Baseline demographic, socioeconomic, clinical, anthropometric, and physical activity characteristics of hemodialysis patients allocated to the control and intervention groups. Continuous variables are expressed as mean ± standard deviation or median (interquartile range), and categorical variables as frequencies and percentages. *P*-values indicate between-group comparisons.

| | | Total (n=41)<br>n (SD) | % | *P*-value | CG (n = 13)<br>n (SD) | % | IG (n=28)<br>n (SD) | % |
|---|---|---|---|---|---|---|---|---|
| Average weight (kg) | | 68.2 ± 14.6 | | 0.39 | 64.75±17.42 | | 69.63± 13.43 | |
| Average height (m) | | 1.63 ± 0.11 | | 0.60 | 1.62±0.14 | | 1.64 ± 0.10 | |
| Average of BMI | | 25.4 ± 4.99 | Overweight | 0.61 | 24.68 ± 6.3 | Overweight | 25.7 ± 4.44 | Overweight |
| Average age (years) | | 56.5 ±10.22 | | 0.97 | 55 ± 12.4 | | 57.24 ± 9.3 | |
| High abdominal circumference | | 81% | | 0.92 | 73% | | 85% | |
| Sex | Masculine | 20 | 48.78 | 0.73 | 7 | 58 | 14 | 50 |
| | Feminine | 21 | 51.22 | | 5 | 42 | 14 | 50 |
| BMI classification | Underweight | 1 | 2.44 | 0.42 | 1 | 8.3 | - | 0 |
| | Eutrophic | 18 | 43.15 | | 6 | 50 | 12 | 42.8 |
| | Overweight | 14 | 34.15 | | 3 | 25 | 11 | 39.3 |
| | Obesity 1 | 6 | 14.63 | | 1 | 8.3 | 5 | 17.9 |
| | Obesity 2 | 2 | 4.88 | | 1 | 8.3 | 1 | 3.6 |
| | Above normal weight | 22 | 53.66 | | 5 | 41.6 | 17 | 60.71 |
| Education | No schooling | 5 | 12.2 | 0.08 | - | 0 | 5 | 17.9 |
| | Primary school | 21 | 51.22 | | 6 | 50 | 15 | 53.5 |
| | Secondary school incomplete | 5 | 12.2 | | 2 | 16.3 | 3 | 10.7 |
| | Secondary school complete | 6 | 14.63 | | 4 | 33.3 | 2 | 7.14 |
| | Higher education | 4 | 9.76 | | - | 0 | 4 | 14.28 |
| Income | < 1 minimum wage | 6 | 14.63 | 0.001 | - | 0 | 6 | 21.42 |
| | 1 – 3 minimum wages | 23 | 56.1 | | 4 | 33.3 | 19 | 67.9 |
| | 3 – 6 minimum wages | 3 | 7.32 | | 1 | 8.3 | 2 | 7.14 |
| | 6 – 10 minimum wages | 1 | 2.44 | | - | 0 | 1 | 3.6 |
| | > 10 minimum wages | 1 | 2.44 | | - | 0 | 1 | 3.6 |
| | Not provided | 7 | 9,76 | | 7 | 58.3 | - | 0 |
| Comorbidities | Diabetes | 6 | 14.36 | 0.65 | 1 | 8.3 | 5 | 17.8 |
| | Hypertension | 14 | 41.56 | 0.73 | 4 | 33.3 | 13 | 46.4 |
| IPAQ | | n | | | Evaluation | | Re-evaluation | |
| | | | | % | n | % | | |
| | Very active | | 0.36 | 1 | 2.44 | 4 | 9.76 | |
| | Active | | | 9 | 21.95 | 10 | 24.39 | |
| | Irregularly active A | | | 11 | 26.83 | 12 | 29.27 | |
| | Irregularly active B | | | 12 | 29.27 | 10 | 24.39 | |
| | Sedentary | | | 8 | 19.51 | 5 | 12.20 | |

BMI: Body mass index; IPAQ: International Physical Activity Questionnaire. Source: Authors.

Table 2 shows that after the intervention, the IG demonstrated significant improvements in Kt/V (0.004), handgrip strength (0.001), and Barthel Index scores (from 92.2 to 96.07; $p$= 0.0021). In contrast, the CG showed a decline in Barthel Index scores (from 96.61 to 94.61; $p$= 0.02). Although the FSS did not yield statistically significant changes, clinical values suggested improvements (scores > 28 indicate fatigue). Kt/V increased in the IG (1.27±0.26

to 1.42±0.32; *p*= 0.004), while decreasing in the CG (1.63±1.06 to 1.32±0.26; *p*= 0.26), indicating enhanced dialysis efficiency in the IG. Lower limbs strength increased in both groups: IG improving (17.4±2.41 to 18.6±1.8; *p*= 0.04) and CG (15.5±2.43 to 17.9±3.14; *p*= 0.14).

FTSTS results were not statistically significant in either group: IG (17.0±6.6 to 17.9±6.74; *p*= 0.38) and CG (17.32±5.92 to17.4±3.93; *p*= 0.33), possibly influenced by factors such as balance and movement speed. Handgrip strength increased in the IG (23.64±11.38 to 29.29±13.2; *p*= 0.001), whereas the CG exhibited only a negligible, non-statistically significant change (26.45±20.10 to 27.8±12.15; *p*= 0.84). Regarding the FSS, IG patients reported reduced fatigue, with a mean score decreasing from (30.6±15.35 to 23.92±15.50; *p*= 0.09), falling below the fatigue threshold. The CG also showed a decrease (27±15.5 to 20.07±6.2; *p*=0.07), but it was not statistically significant. As for KDQoL, no significant differences were observed between the groups. The Barthel Index indicated improved functional independence in the IG (92.2±9.36 to 96.07±4.4; *p*= 0.0021) and a slight but significant decrease in the CG (96.61±16.91 to 94.61±1.6; *p*= 0.02).

Table 2. Pre- and Post-Intervention Statistics

| | Intervention Group | | | Control Group | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pre | Post | *p* value | Pre | Post | *p* value | *p* value TOTAL | Hedge's G values | |
| Dialytic efficiency | 1.27±0.26 | 1.42±0.31 | 0.004 | 1.63±1.06 | 1.32±0.26 | 00.26 | 0.18 | 00.77 | Moderate |
| Lower limb strength | 17.4±2.41 | 18.6±1.8 | 0.04 | 16±2.69 | 17.9±3.14 | 00.14 | 0.91 | --0.27 | Small |
| FTSTS | 17.0±6.6 | 17.9±6.74 | 0.38 | 17.32±5.92 | 17.4±3.93 | 00.33 | 0.26 | 00.3 | Insignificant |
| Handgrip | 23.64±11.38 | 29.29±13.2 | 0.001 | 26.45±20.10 | 27.8±12.15 | 00.084 | 0.12 | 00.28 | Small |
| Fatigue Scale | 30.6±15.35 | 23.92±15.5 | 0.09 | 27±15.5 | 20.07±6.2 | 00.71 | 0.61 | 00.01 | Insignificant |
| Quality of life | 36.41±12.27 | 38.9±8.2 | 0.129 | 34.31±11.51 | 34.88±6.2 | 00.41 | 0.78 | 00.19 | Insignificant |
| Independence | 92.2±9.36 | 96.07± 4.4 | 0.0021 | 96.61±1.69 | 94.61±1.69 | 00.02 | 0.4 | 11.08 | Large |

dialytic efficiency: Kt/V, lower limb strength: MRC (MMII: lower limbs), FTSTS: Five Times Sit-to-Stand Test, Handgrip: Handgrip strength measured by dynamometry, Fatigue Scale: FSS (Fatigue Severity Scale), quality of life: KDQoL-SF (Kidney Disease Quality of Life – Short Form), Independence: Barthel Index.

Table 3 presents the multivariate analysis, showing that the protocol exerted a mild yet clinically relevant effect, particularly on functional independence (*p*= 0.07), the FTSTS test (*p*= 0.06), and Kt/V (*p*= 0.01). Body weight was associated with functional independence (*p*= 0.08), height correlated with SARC-F scores (*p*= 0.07), and BMI was related to MRC outcomes (*p*= 0.05), handgrip strength (*p*= 0.04), and functional independence (*p*= 0.08), highlighting its relevance in response to the intervention.

Table 3. MANOVA (Multivariate Analysis of Variance) is a statistical test that simultaneously evaluates differences between groups across two or more dependent variables.

| | Participation | Weight | Height | BMI | Age | Diabetes | Hypertension | Education | Sex |
|---|---|---|---|---|---|---|---|---|---|
| Abdominal circumference | 1.12 (0.29) | 0.47 (0.49) | 0.97 (0.33) | 0.03 (0.84) | 0.80 (0.37) | 2.10 (0.15) | 2.77 (0.10) | 2.68 (0.04) | 4.7 (0.03) |
| Lower limb strength | 0.46 (0.50) | 2.74 (0.10) | 0.40 (0.53) | 3.80 (0.05) | 0.26 (0.61) | 2.59 (0.11) | 0.007 (0.93) | 0.52 (0.71) | 0.37 (0.54) |
| FTSTS | 3.49 (0.06) | 0.05 (0.81) | 0.08 (0.77) | 0.28 (0.59) | 0.15 (0.69) | 2.06 (0.16) | 1.49 (0.22) | 2.95 (0.03) | 0.28 (0.59) |
| Handgrip | 2.4 (0.12) | 0.21 (0.64) | 0.61 (0.43) | 4.42 (0.04) | 0.03 (0.86) | 1.04 (0.31) | 0.008 (0.92) | 1.37 (0.26) | 3.11 (0.08) |
| FSS | 0.091 (0.74) | 0.07 (0.79) | 0.00 (0.95) | 1.55 (0.22) | 0.45 (0.50) | 1.18 (0.28) | 2.21 (0.92) | 1.03 (0.40) | 2.88 (0.09) |
| Quality of life | 0.22 (0.63) | 1.73 (0.19) | 1.00 (0.32) | 0.01 (0.90) | 0.47 (0.49) | 0.0001 (0.17) | 0.306 (0.14) | 0.27 (0.89) | 0.19 (0.66) |
| Sarcopenia | 0.50 (0.48) | 0.03 (0.86) | 3.45 (0.07) | 0.16 (0.68) | 0.03 (0.84) | 2.32 (0.13) | 0.009 (0.92) | 0.89 (0.47) | 0.47 (0.49) |
| Physical activity | 1.42 (0.24) | 0.23 (0.62) | 0.33 (0.56) | 0.12 (0.73) | 0.01 (0.92) | 0.0006 (0.93) | 0.12 (0.72) | 0.27 (0.89) | 0.16 (0.69) |
| Independence | 3.37 (0.07) | 3.16 (0.08) | 0.51 (0.47) | 3.13 (0.08) | 1.90 (0.17) | 0.85 (0.36) | 0.25 (0.61) | 0.28 (0.88) | 3.41 (0.07) |
| Kt/V | 6.51 (0.01) | 0.00 (0.96) | 0.78 (0.38) | 0.63 (0.43) | 0.13 (0.71) | 0.03 (0.85) | 0.308 (0.58) | 1.41 ( 0.25) | 3.03 (0.09) |

dialytic efficiency: Kt/V, lower limb strength: MRC (MMII: lower limbs), FTSTS: Five Times Sit-to-Stand Test, Handgrip: Handgrip strength measured by dynamometry, Fatigue Scale: FSS (Fatigue Severity Scale), physical activity: IPAQ (International Physical Activity Questionnaire), sarcopenia: SARC-F, quality of life: KDQoL-SF (Kidney Disease Quality of Life – Short Form), independence: Barthel Index, diabetes, hypertention education, sex.

Table 4 reports the relationship between BMI, Kt/V, abdominal circumference (AC), and DM. Individuals with diabetes had a mean BMI 19% higher than their non-diabetic counterparts (29.41 *vs* 24.72 kg/m$^2$; $p$= 0.02). Kt/V was significantly lower in the diabetic patients ($p$< 0.05), falling below the recommended minimum threshold of 1.2, indicating reduced dialysis efficiency. Notably, five of the six diabetic patients were classified as overweight or obese, reinforcing the association between DM, increased body mass, and suboptimal dialysis performance. Table 5 summarizes changes in fatigue across the groups. In the IG, the number of fatigued individuals decreased from 19 to 11, whereas in the CG it increased from 16 to 24. The baseline $p$-value was 0.6; after the intervention, it decreased to 0.027, indicating a statistically significant difference. Notably, eight patients in the IG no longer met criteria for fatigue, supporting the protocol's beneficial effect.

Table 4. Relationship of Diabetes Mellitus with Other Measures.

| | | With diabetes (SD and Median) | Without diabetes (SD and median) | *p* -value * |
|---|---|---|---|---|
| Kt/V | | 1.145±0.22 | 1.434±0.66 | 0.0006 |
| Abd. Circ. | | 104±11.80 | 95±12.88 | 0.15 |
| BMI | | 29.41±3.6 | 24.72±4.9 | 0.024 |
| | | **Relation DM x BMI** | | |
| | | **With diabetes** | **Without diabetes** | |
| Diabetes mellitus | Underweight | 0 | 1 | |
| | Eutrophic | 1 | 17 | |
| | Overweight | 1 | 13 | 0.004 |
| | Obesity 1 | 4 | 2 | |
| | Obesity 2 | 0 | 2 | |

bmi: body mass index, dm: diabetes mellitus, ndm: no diabetes mellitus, abd. circ: abdominal circumference, Kt/V: dialytic efficiency. pre-intervention values, Parametric t-test.

Table 5: The indicative presence of sarcopenia was assessed using the SARC-F questionnaire, and fatigue was evaluated using the FSS, in both the assessment and reassessment of participants in the exercise protocol and the control group.

| **Fatigue** | **With fatigue n (%)** | **Without fatigue n (%)** | ***p*-value** |
|---|---|---|---|
| Evaluation | 19 (54) | 16 (46) | 0.61 |
| Reevaluation | 11 (31) | 24 (69) | 0.027 |
| **Protocol participation** | **No** | **Yes** | ***p*-value** |
| No | 10 | 3 | 0.89 |
| Yes | 21 | 7 | |
| No | 11 | 2 | 0.17 |
| Yes | 27 | 1 | |

As shown in Table 6, baseline differences were observed across KDQoL strata. Fatigue severity was higher in the high quality-of-life group (41.8±13.3) compared with the moderate (26.1±14.3) and low QoL groups (23.2±11.7). Muscle strength assessed by the MRC scale was lower among participants classified as having high KDQoL (15.4±2.36) than in those with moderate and low quality of life (17.5±2.34 and 17.5±2.47, respectively). Baseline Kt/V values were comparable across QoL classifications, ranging from 1.25±0.33 in the moderate group to 1.36±0.33 in the low group. Abdominal circumference tended to be slightly higher in the low (97.5±12.2) and moderate quality-of-life groups (98.0±13.6) compared with the high QoL group (95.0±14.1).

Table 6. Descriptive statistics of clinical and functional variables in the pre- and post-intervention periods, stratified according to KDQoL classification.

| Clinical and Functional Outcomes by KDQoL Classification | | | | |
|---|---|---|---|---|
| | | Low<br>Mean (sd) | Moderate<br>Mean (sd) | High<br>Mean (sd) |
| KT/V | Pre | 1.36 (0.33) | 1.25 (0.33) | 1.26 (0.26) |
| | Post | 1.41 (0.22) | 1.39 (0.28) | 1.38 (0.40) |
| AC | Pre | 97.5 (12.2) | 98.0 (13.6) | 95.0 (14.1) |
| | Post | 96.9 (13.8) | 96.2 (10.7) | 96.3 (13.8) |
| MRC | Pre | 17.5 (2.47) | 17.5 (2.34) | 15.4 (2.36) |
| | Post | 25.0 (23.3) | 24.0 (19.9) | 18.2 (2.33) |
| FSS | Pre | 23.2 (11.7) | 26.1 (14.3) | 41.8 (13.3) |
| | Post | 12.7 (6.74) | 24.2 (17.4) | 31.4 (14.5) |

Data are presented as mean (sd). KDQoL categories were defined as follows: low (≤ 32.92), moderate (32.93–40.19), and high (≥ 40.20). KDQoL: Kidney Disease Quality of Life; Kt/V: dialysis adequacy; CA: abdominal circumference; MRC: Medical Research Council scale; FSS: Fatigue Severity Scale; IPAQ: International Physical Activity Questionnaire.

After the intervention, distinct response patterns were observed among KDQoL strata. The low KDQoL group showed the most pronounced changes, with MRC scores increasing from 17.5±2.47 to 25.0±23.3 and FSS scores decreasing from 23.2±11.7 to 12.7±6.74. In the moderate KDQoL group, muscle strength increased from 17.5±2.34 to 24.0±19.9, while fatigue showed a smaller reduction, from 26.1±14.3 to 24.2±17.4. In contrast, the high KDQoL group demonstrated more modest improvements, with MRC scores increasing from 15.4±2.36 to 18.2±2.33 and FSS scores decreasing from 41.8±13.3 to 31.4±14.5. Increases in Kt/V were observed across all groups, reaching 1.41±0.22 in the low, 1.39±0.28 in the moderate, and 1.38±0.40 in the high KDQoL groups, while abdominal circumference remained relatively stable in all strata.

Additionally, the number of participants with a SARC-F score ≥ 5 decreased, suggesting a lower risk of sarcopenia among those adhering to the exercise protocol, yielding an initial dataset of 203 articles, which supported the bibliometric screening phase. The clusters in Fig. 2 illustrate distinct dimensions of exercise effects in CKD patients on HD, and the network structure was generated through a scientometric mapping based on the analysis of 69 indexed articles. The red cluster represents exercise type and intensity for muscular adaptation; the yellow cluster highlights aerobic benefits and reduction of oxidative stress; the blue cluster reflects reduced fatigue and sedentary behavior; and the green cluster emphasizes improvements in QoL and overall health, such as pain relief and enhanced body composition. Collectively, these clusters demonstrate the multifaceted role of exercise in CKD management.

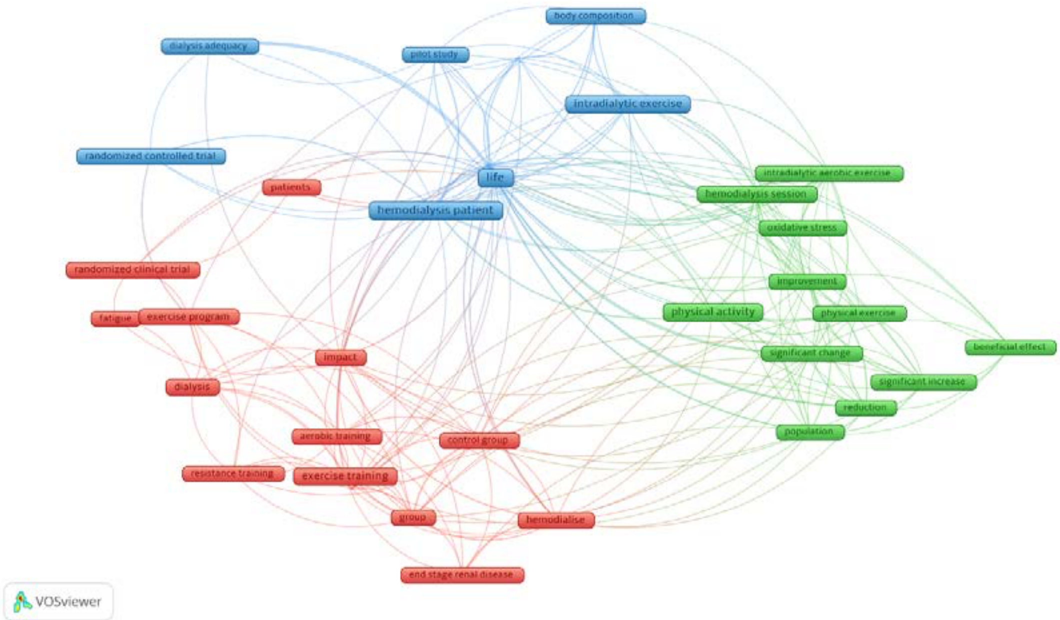


Figure 2. VOSviewer. Network visualization map for common terms among the selected articles. Clusters are formed among similar images. 2024.

Fig. 3 shows the evolution of the research topics, indicating that recent studies increasingly address physical exercise during and outside HD sessions, with a broader emphasis on QoL and overall well-being, whereas earlier studies predominantly focused on treatment adaptation and fatigue reduction. The color-coding of the nodes depicts this progression: older studies cluster around fatigue and sedentary behavior, while more recent ones relate to concepts such as "visual reality" and "body composition", reflecting a shift toward more integrative and biopsychosocial approaches in CKD care.

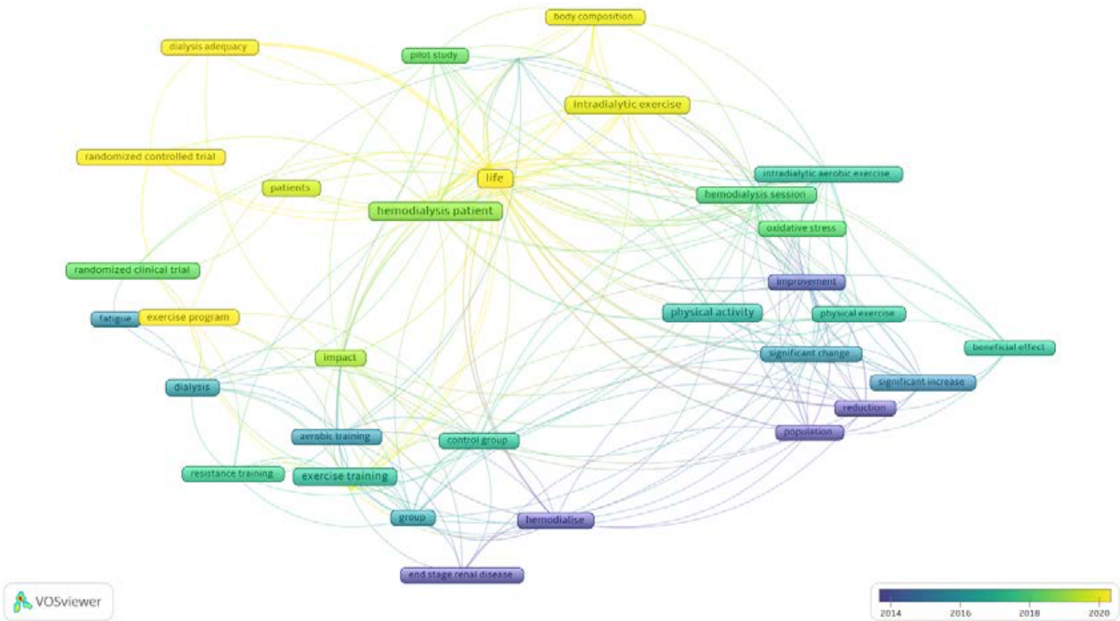


Figure 3. VOSviewer: Network visualization map of recurring terms over time in the analyzed articles. Terms in blue represent older mentions, while terms in yellow indicate more recent approaches in publications up to 2024.

## DISCUSSION

Patients with CKD undergoing HD often present marked physical limitations and heightened risk of sarcopenia, reinforcing the relevance of investigating intradialytic exercise as an adjunct therapeutic approach. In the studied Brazilian region, adverse socioeconomic conditions pose additional barriers to healthcare access and the provision of quality services, making both prevention and chronic disease management more difficult and requiring targeted public health strategies.[36] Practical constraints, notably lower income and reduced educational attainment, not only worsen the clinical CKD prognosis but also disrupt the balance between professional healthcare delivery and self-care practices, compromising treatment adherence and diminishing overall QoL.[37] Consistent with Purtell and coworkers (2024), lower income is associated with restricted access to healthcare services and poorer clinical outcomes.[38]

Although the QoL questionnaire demonstrated that CKD affected QoL by approximately 30%, higher values have been reported in other studies.[39] The intervention protocol did not yield statistically significant changes in QoL, which is expected given its dependence on multiple, interconnected factors, including physical condition, psychological status, and social context.[40] Functional independence showed a meaningful post-intervention amelioration, suggesting a beneficial effect.[41]

The STSTS, used to assess lower-limb strength and fall risk, did not show significant changes. Since balance depends on visual, proprioceptive, and vestibular systems, these may have influenced the absence of observed functional improvement.[42] Nevertheless, lower-limb strength, as measured by the MRC scale, improved, potentially reflecting both physiological adaptation and familiarization effects inherent to repeated testing, in addition to examiner-related influences.[43] Handgrip strength increased significantly in the IG, suggesting broader improvements in muscle strength.

Overweight individuals showed greater strength, possibly due to higher body mass and the resulting greater mechanical demand on muscles during daily activities; however, this does not reflect better muscle condition or confer health benefits.[44]

The intradialytic exercise protocol resulted in significant within-group improvements in health and behaviour, particularly physical activity levels, as evidenced by increased IPAQ scores. This suggests improved adherence to healthier habits and greater attention to body weight control. A marked reduction in fatigue was also observed, especially in IG, where several participants were no longer classified as fatigued, indicating a direct and beneficial effect of the intervention.[45]

There was also a significant decrease in SARC-F scores, indicating reduced sarcopenia risk and improved functionality.[46] Despite the well-known propensity for muscle loss in dialysis patients, the findings demonstrated favourable effects of exercise on muscle preservation and clinical outcomes.[47]

These benefits may be associated with the modulation of systemic inflammation, a standard feature in CKD patients. Another key finding was improved dialysis efficiency in the IG, suggesting greater clearance of uremic solutes[48] and a positive physiological response to exercise, potentially optimizing blood perfusion,[49] protein synthesis,[48] and nutritional status.[50] In contrast, the CG showed deterioration in these indicators, which could be influenced by unmeasured behavioral factors. Anthropometric analysis showed that most participants (85%) had an abdominal circumference above the relevant value of 80 cm for women and 94 cm for men, a factor associated with cardiovascular risk.[51] Diabetic patients exhibited even higher measurements and a greater prevalence of overweight/obesity, reinforcing the vulnerability.

The results indicate that baseline KDQoL classification was associated with distinct clinical and functional profiles and influenced responsiveness to the intervention.[52] Participants classified with higher KDQoL exhibited greater fatigue severity and lower muscle strength at baseline compared with those in the low and moderate KDQoL groups, despite similar dialysis adequacy across strata. This finding underscores the multidimensional nature of quality of life in chronic kidney disease,[53] suggesting that patient-reported well-being does not necessarily parallel objective functional status or symptom burden.[54]

Following the intervention, individuals with lower KDQoL demonstrated more pronounced improvements in muscle strength and fatigue reduction, whereas those with moderate KDQoL showed intermediate responses.[55] In contrast, participants with higher KDQoL exhibited smaller functional gains and less marked symptom improvement, despite comparable increases in Kt/V.[56] Warrant further investigation regarding a potential ceiling effect in patients with better perceived quality of life at baseline[57] and highlight the relevance of KDQoL-based stratification for identifying patients more likely to benefit from clinical and functional interventions.[58]

The relevance of this clinical trial lies not only in the physiological and functional benefits observed but also in its implementation in a region characterized by socioeconomic hardship and logistic healthcare challenges.[36] Recruiting and retaining patients in intradialytic exercise programs in such a highly vulnerable population, where access to care and treatment adherence are notably compromised, represents a substantial challenge. Thus, this describes the feasibility, safety and effectiveness of this adapted protocol.

Despite limitations, such as the short timeframe for more comprehensive evaluation and participant attrition during follow-up, the findings reinforce the value of regular physical exercise as an adjunct therapeutic strategy in HD. The intervention improved muscle strength, reduced fatigue, and enhanced functional capacity. Key outcomes included increased handgrip strength, higher IPAQ scores, greater independence, lower SARC-F scores, and improved dialysis efficiency, indicating meaningful physiological benefits.

## CONCLUSION

This study supports the feasibility and potential effectiveness of a supervised intradialytic exercise protocol as an intervention for adults with CKD, even in a socioeconomically vulnerable context. The improvements observed in dialysis adequacy, handgrip strength, and functional independence highlight the clinical value of this non-pharmacological strategy in mitigating the deleterious effects of the disease. These findings reinforce the importance of integrating physical rehabilitation into routine hemodialysis care as a low-cost, high-impact measure to improve health outcomes within the public health system.


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### Contributorship Statement

**ORJ** had full access to all study data and ensured the integrity of the analysis. Study conception, design, supervision, and methodology were supported by **ORJ, PAC, WCS, ACDB, CRD, RF, RCR,** and **JSB,** including data curation and formal analysis. Writing, review, editing, and translation were handled within predefined author roles.

All authors — **ORJ, PAC, WCS, ACDB, CRD, RF, RCR,** and **JSB** — reviewed and approved the final manuscript and accepted accountability for all aspects of the work.

### Ethical Disclosures

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**Confidentiality of Data:** The authors declare that they have followed the protocols of their work center on the publication of patient data.

**Protection of Human and Animal Subjects:** The authors declare that the procedures followed were in accordance with the regulations of the relevant clinical research ethics committee and those of the Code of Ethics of the World Medical Association (Declaration of Helsinki as revised in 2024).

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