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Research Paper

Impact of Intradialytic Exercise on Infection Rate and Calcium–phosphate Product in Pediatric Hemodialysis Patients: A Pilot Study

Neda Ghorbani-Khosroshahi[1], Masoumeh Mohkam[2], Reza Ghorbani-Khosroshahi[3*], Mohammad Reza Kordi[4], Amir Hossein Saffar Kohneh Quchan[4], Marzieh Babaee[5], Leila Saremi[4]

1. Department of Pediatrics, School of Medicine, Children Medical Research and Training Hospital, Tabriz University of Medical Sciences, Tabriz, Iran.
2. Pediatric Nephrology Research Center, Research Institute for Children's Health, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
3. Pediatric Infection Research Center, Research Institute for Children' Health, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
4. Department of Exercise Physiology, Faculty of Sport Sciences and Health, University of Tehran, Tehran, Iran.
5. Physical Medicine and Rehabilitation Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

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Corresponding Author:
Reza Ghorbani-Khosroshahi
Address: Pediatric Infection Research Center, Research Institute for Children' Health, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
E-mail: rezaghorbani.kh@ut.ac.ir

ABSTRACT

Background and Aim: Children with end-stage chronic kidney disease on maintenance hemodialysis (HD) are highly susceptible to infections (catheter-related, urinary tract, and upper respiratory) and disturbances in calcium–phosphate (Ca×P) metabolism. Intradialytic exercise has been proposed as a safe non-pharmacologic strategy to improve physical function and reduce inflammation; however, data in pediatric populations remain scarce. This pilot study aimed to evaluate the feasibility of an 8-week combined intradialytic exercise program and explore its effects on the infection rate and the Ca×P product.

Methods: This quasi-experimental single-group pre–post pilot study was conducted in five children (aged 8–18 years) with maintenance HD ≥2 months and a stable central venous catheter. The intervention comprised supervised upper-limb resistance and supine cycling exercise three times per week during HD sessions for 8 weeks. Infection events were recorded using standardized clinical and laboratory criteria. Serum calcium and phosphate were measured pre- and post-intervention; Ca×P product was calculated. Prepost Ca×P changes were analyzed with a paired t-test; infection rates during exercise versus non-exercise months were compared using the Mann–Whitney U test ($P<0.05$).

Results: All five participants completed the program. The mean Ca×P increased non-significantly from 52.7±17.71 to 59.43±8.43 mg^2/dL^2 ($P=0.36$). Mean monthly infection rate was 10% during exercise months versus 16% during non-exercise months ($P=0.673$). The exercise protocol was feasible and well-tolerated.

Conclusion: An 8-week combined intradialytic exercise program was feasible and safe in pediatric patients with HD. It did not significantly alter infection rates or Ca×P product in this small, underpowered pilot study. Larger randomized controlled trials are needed.

Keywords: Chronic kidney disease (CKD), Intradialytic exercise, Infection, Calcium-phosphate (Ca×P) product, Pediatric, Hemodialysis (HD)

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J Ped Nephrol
Journal of Pediatric Nephrology

Introduction

Chronic kidney disease (CKD) in children is associated with considerable morbidity, particularly in those who progress to end-stage kidney disease and require maintenance hemodialysis (HD). Among pediatric HD patients, infectious complications are a major cause of hospitalization and adverse clinical outcomes. The frequent use of central venous catheters (CVCs), combined with uremia-related immune dysfunction and repeated exposure to healthcare settings, increases susceptibility to catheter-related bloodstream infections as well as urinary and respiratory tract infections [1-4]. Despite advances in infection-control strategies, infectious morbidity remains a persistent clinical challenge in this vulnerable population.

In parallel, children receiving HD commonly experience disturbances in mineral metabolism, known as CKD–mineral and bone disorders. Abnormalities in calcium–phosphate (Ca×P) homeostasis, particularly an elevated Ca×P product, have been associated with vascular calcification and adverse cardiovascular outcomes [5]. Emerging pediatric evidence also suggests that Ca×P imbalance may contribute to musculoskeletal symptoms and reduced physical function in children undergoing dialysis [6]. These metabolic and infectious burdens collectively impair quality of life and long-term prognosis.

Intradialytic exercise, performed during HD sessions, has emerged as a feasible non-pharmacological strategy to improve physical function and modulate systemic inflammation in dialysis patients [7].

Adult studies have indicated potential benefits on inflammatory markers and mineral metabolism; however, evidence regarding its impact on infection rates and Ca×P in pediatric HD patients remains limited.

Therefore, this pilot study aimed to evaluate the feasibility and short-term effects of an eight-week combined intradialytic exercise program on infection rates and the Ca×P product in children undergoing maintenance HD.

Materials and Methods

This quasi-experimental, single-group pre-post pilot study was conducted over eight weeks at the Pediatric Nephrology Unit of Mofid Children's Hospital in Tehran, Iran. The intervention involved a combined intradialytic exercise program, and outcome measures were collected at baseline and after the intervention to evaluate its effects on infection rates and the Ca×P product in pediatric HD patients.

Study population

Eligible participants were children aged 8–18 years diagnosed with end-stage CKD who had been receiving maintenance HD for a minimum of two months. Inclusion criteria required stable CVC access, no participation in structured exercise within the preceding six months, and no lower-limb musculoskeletal disorders or grafts. Exclusion criteria included the presence of femoral or internal jugular catheters, any recent infectious episode, or referral for kidney transplantation during the study period. Among 11 initially screened patients, nine met the eligibility criteria; however, four were later excluded due to transplantation referral (n=2), transfer to another dialysis center (n=1), and catheter modification (n=1), leaving five participants who completed the study.

Outcome measures

Catheter-related infections (CRI), urinary tract infections (UTI), upper respiratory tract infections (URTI), cough, symptoms of rhinitis (such as runny nose and sore throat), and malaise were considered as potential infections in the pediatric population. The presence of infection in these children was evaluated based on clinical observations, infection-related symptoms, and positive blood test results. Specifically, CRI was diagnosed when the child exhibited clinical signs of infection, such as fever or chills, and when blood cultures from both the catheter and a peripheral vein were positive, in the absence of other identifiable infectious foci. In addition, UTI and URTI were diagnosed based on clinical assessments and laboratory findings, including elevated C-reactive protein (CRP) levels, white blood cell (WBC) counts, and positive cultures, along with clinical symptoms. For UTI, clinical symptoms included dysuria, abdominal pain, fever, and in some cases general malaise. For URTI, clinical symptoms included cough, rhinitis (e.g. runny nose), sore throat, and malaise. All infectious events were confirmed by measurement of CRP and white blood cell (WBC), as well as positive culture results. Standardized methods recommended in clinical guidelines, including those of the Centers for Disease Control and Prevention, were followed for the evaluation of CRI, UTI, and URTI [8-15].

Serum total calcium (Ca, mg/dL) and phosphate (P, mg/dL) levels were assessed twice: immediately before the start of the intradialytic exercise program and after completion of the 8-week intervention, using values from the hospital's routine laboratory testing. For each time point and participant, Ca×P (mg^2/dL^2) was calculated as the product of total serum Ca and P and used as a composite marker of mineral metabolism.

Demographic and clinical information, including age, sex, duration of dialysis treatment, and existing comorbidities, were obtained using structured questionnaires.

Procedures

Departmental approval was obtained prior to study initiation, and the procedures were fully explained to both parents and participating children, after which written informed consent was secured. A preliminary pilot involving two children was conducted to confirm the feasibility and safety of the protocol.

Pre- and post-intervention assessment phase

Prior to the formal initiation of the study, the exercise protocol was piloted in two pediatric participants to assess the feasibility and safety of all training components. Baseline assessments were conducted before the intervention and included infection rate monitoring, measurement of serum calcium and phosphorus levels, and collection of demographic and relevant clinical data. Following completion of the eight-week intervention, the same evaluations were repeated to enable within-patient comparisons and to determine potential changes attributable to the combined intradialytic exercise program.

Intervention phase

Following connection to the HD circuit at the start of the first treatment hour, each child initiated an eight-week intradialytic exercise regimen performed three times per week on nonconsecutive dialysis days. Sessions began with a five-minute warm-up consisting of static and dynamic stretching of the major muscle groups to increase muscle temperature, improve joint mobility, and reduce the risk of injury. After a two-minute passive rest, participants engaged in upper-limb resistance training using pediatric dumbbells. The selected exercises—dumbbell curl, forearm supination and pronation, and hammer curl—primarily targeted the biceps brachii and forearm flexor musculature. Training loads were individualized according to each child's ten-repetition maximum (10 RM). All resistance exercises were performed in two sets of 10 repetitions with 90 s of passive rest between sets. Resistance training was deliberately scheduled before aerobic activity to mitigate fatigue and preserve performance quality.

Upon completion of the resistance component, a further two-minute passive rest was provided. Aerobic exercise was then performed using a supine cycle ergometer secured to the dialysis bed, offering 12 adjustable speed levels. During weeks 1–4, participants cycled for 10 minutes, which increased to 15 minutes during weeks 5–8. The participants were instructed to match their pedaling cadence to the selected speed level and maintain a steady exercise intensity throughout each session. Perceived exertion during both resistance and aerobic segments was continuously assessed using the children's OMNI scale, targeting a rating of 3 ("moderate") in the first month and 5 ("somewhat hard") in the second month. Each exercise session concluded with a five-minute cool-down consisting of static stretches of the muscle groups engaged during the resistance and cycling activities, with each stretch held for 20–30 seconds to support gradual cardiovascular recovery and reduce post-exercise discomfort.

To ensure safety, all exercises were confined to extremities free of vascular access devices (arteriovenous fistula or CVC). A multidisciplinary team—including certified exercise physiologists, a pediatric nephrologist, and dialysis nurses—continuously monitored the patients' vital signs, HD parameters, and perceived exertion. Participants were instructed to report adverse symptoms such as dizziness, muscle cramping, or access-site discomfort immediately. Exercise was discontinued if signs of hemodynamic instability (e.g. systolic blood pressure <90 mm Hg, arrhythmia, or SpO_2<90%) or catheter-related complications emerged. Passive rest intervals of 120 s between major phases and 90 s between resistance sets were implemented to enhance hemodynamic stability. Exercise intensity was adjusted dynamically based on OMNI Scale ratings to ensure safety and therapeutic benefit without compromising dialysis adequacy.

Ethical approval

Ethical approval was granted by the Ethics Committee of the Faculty of Sports Science and Health, University of Tehran, and the study was registered in the Iranian Registry of Clinical Trials. Participant confidentiality was upheld throughout the study.

Statistical analysis

Normality of continuous variables, including serum calcium, phosphate, and the Ca×P product, was assessed using the Shapiro–Wilk test. Because Ca×P values were approximately normally distributed, pre- and post-intervention Ca×P were compared using paired t-tests. A two-sided $P<0.05$ was considered statistically significant. In addition, standardized mean differences (Cohen's d) with 95% confidence intervals (CI) were calculated as effect size estimates for the change in Ca×P.

J Ped Nephrol
Journal of Pediatric Nephrology

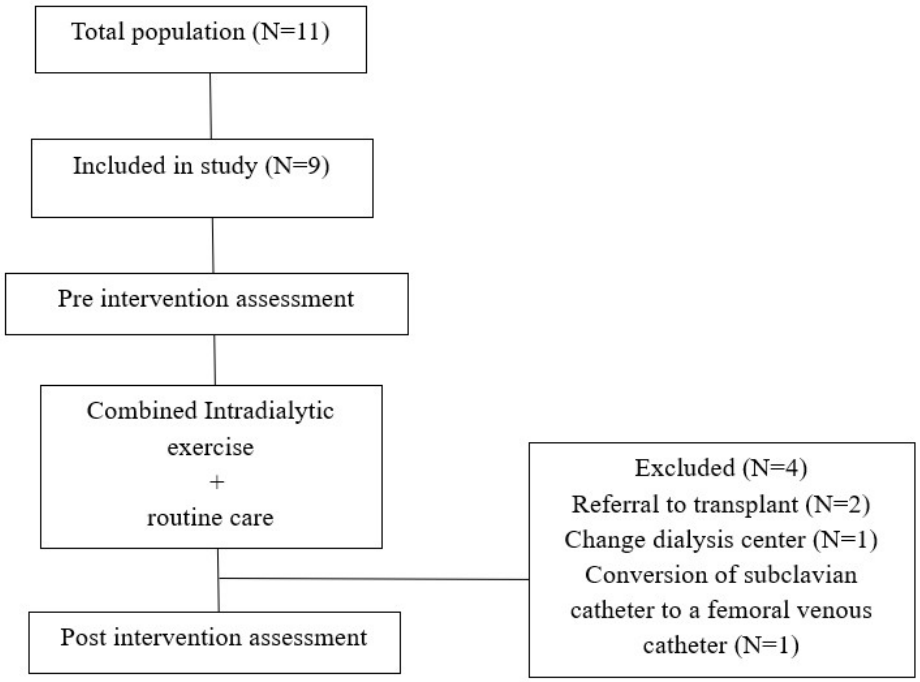

Figure 1. Participant flow diagram in the pilot study of intradialytic exercise in pediatric HD patients

For infection data, which were binary (0=no infection, 1=infection), the Mann-Whitney U test, another non-parametric test, was used to compare infection rates between the exercise months (November and December) and the other months. This test was selected as it is suitable for comparing non-normally distributed data. A significance level of 0.05 was used for all comparisons, and $P<0.05$ were considered statistically significant.

Results

Patient characteristics

The children's age ranged from 8 to 18 years. Figure 1 shows the flow of participants through the study, including screening, eligibility assessment, enrollment, and reasons for discontinuation. Of the nine children who initiated the combined intradialytic exercise program, five completed the full intervention period. Four participants were withdrawn for the following reasons: referral for kidney transplantation (n=2), transfer to another dialysis center (n=1), and conversion from a subclavian to a femoral venous catheter (n=1). In terms of gender, 4 children were male, and 1 was female.

Ca×P product

Five children had complete paired measurements of the Ca×P product before and after the eight-week intradialytic exercise program. Mean baseline Ca×P was 52.7±17.71 mg^2/dL^2 and increased to 59.43±8.43 mg^2/dL^2 at week 8. The mean within-patient change was 6.73±12.69 mg^2/dL^2, with a 95% CI from −13.41 to 26.91 mg^2/dL^2. The paired t-test showed no statistically significant difference between pre- and post-intervention Ca×P values (P=0.36), indicating that the eight-week combined intradialytic exercise program did not produce a detectable change in Ca×P in this small pediatric HD cohort. These data are summarized in Table 1 and illustrated in Figure 2.

Infection rates

The incidence of infections was compared between November and December (when the intradialytic exer-

Table 1. Serum calcium, phosphate, and calcium-phosphate product levels before and after the 8-week intradialytic exercise program

Laboratory Data	Baseline	8 WK	P	Mean Differences (95% CI)
Ca×P (mg^2/dL^2)	52.70 (17.71)	59.43 (8.43)	0.36	6.73 (-13.41, 26.91)

Abbreviations: CI: Confidence interval; Ca×P: Calcium–phosphate.

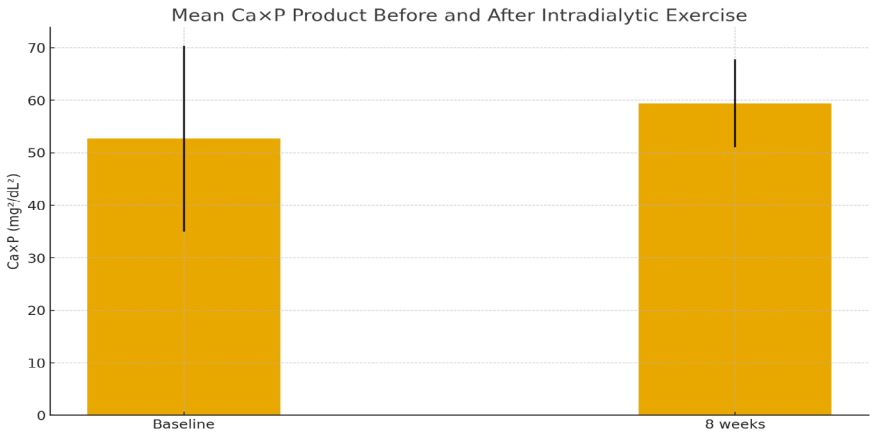

Figure 2. Mean Ca×P product at baseline and after the 8-week intradialytic exercise program in pediatric HD patients

cise program was implemented) and the other months. In November, no infections were reported, while in December, 20% of patients experienced infections. In contrast, infection rates in other months (August, October, January, February, and March) ranged from 0% in August, October, and January to 40% in February and March.

The overall mean infection rate was 10% during the exercise months (November and December) and 16% during the non-exercise months. Statistical analysis using the Mann-Whitney U test revealed no significant difference between the two groups (P=0.673), indicating that the intradialytic exercise program did not have a statistically significant impact on infection rates. These data are illustrated in Figure 3.

Discussion

This pilot study evaluated the feasibility and short-term effects of an eight-week combined intradialytic exercise program on infection rates and the Ca×P product, in children undergoing maintenance HD. In this small cohort, infection rates during the exercise months did not differ significantly from non-exercise months, and mean Ca×P values showed a non-significant numerical increase from baseline to week 8, underscoring that the intervention was safe but underpowered to demonstrate efficacy on these outcomes [16].

Pediatric patients receiving renal replacement therapy are known to have a high burden of infection-related morbidity and mortality, with infections increasingly recognized as a leading cause of hospitalization and

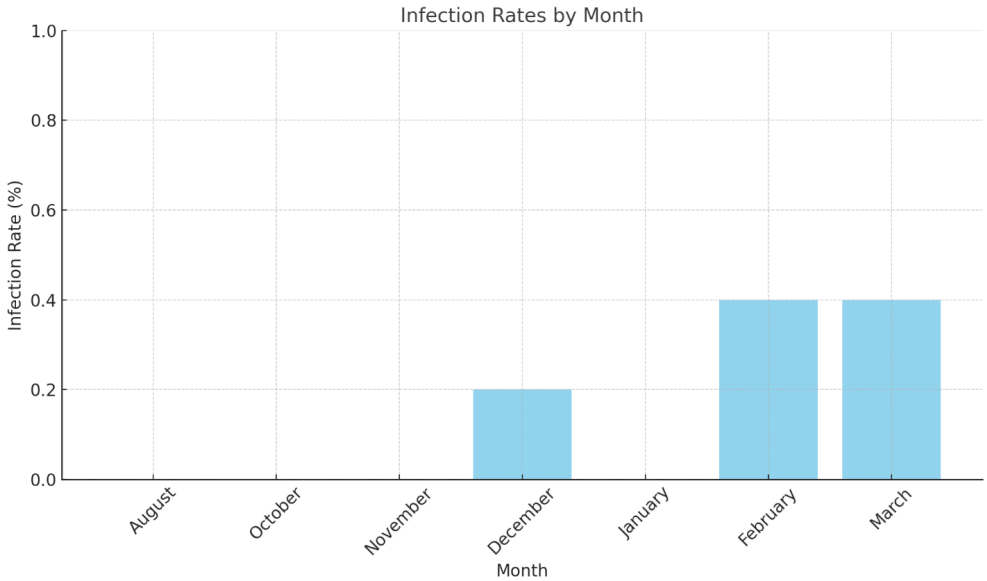

Figure 3. Monthly infection rates in pediatric HD patients

death in long-term follow-up studies [17]. CVCs, which are frequently required in children because of technical difficulties with arteriovenous fistula creation, are a major source of catheter-related bloodstream infection and exit-site infection [1, 18]. Authoritative guidelines emphasize that meticulous catheter care, surveillance, and infection-control measures are essential to reduce these events, yet even in optimized settings residual infection risk remains substantial [18].

Our finding that mean monthly infection rates were numerically lower in exercise months (10%) than in non-exercise months (16%), but not statistically significant (P=0.673), is therefore best interpreted as hypothesis-generating and consistent with an underpowered study rather than as evidence of no effect [16].

Beyond CRI, children with CKD and those on dialysis are also at increased risk of UTIs and respiratory tract infections because of uremia-associated immune dysfunction and frequent healthcare exposure [3]. UTIs and URTI have been reported to occur more often and carry greater morbidity in patients with renal insufficiency and in dialysis cohorts than in the general pediatric population [19]. The inclusion of these infections in our composite outcome reflects the real-world spectrum of infectious morbidity faced by pediatric HD patients. The composite outcome including catheter-related, urinary tract, and upper respiratory infections was chosen because it reflects the broad spectrum of infectious morbidity experienced by pediatric HD patients in daily clinical practice. This approach enhances the generalizability of our findings to routine care [4].

Intradialytic exercise has been extensively studied in adult HD populations, where aerobic and resistance protocols have been shown to improve physical performance, dialysis adequacy, blood pressure control, and health-related quality of life [16]. Several trials have reported that intradialytic exercise can reduce systemic inflammation—lowering CRP and interleukin-6 levels—and thereby modulate infection risk and cardiovascular complications. However, randomized data specifically evaluating infection endpoints remain scarce, particularly in pediatric cohorts, and most existing studies were not powered to detect differences in relatively infrequent infectious events [16, 18].

Our neutral findings regarding infection rates therefore align with the broader literature suggesting that intradialytic exercise is unlikely to substantially increase infection risk and may be safely integrated into routine pediatric HD care, while larger trials are needed to determine whether it can meaningfully reduce infections [17].

The Ca×P product remains a central composite marker of mineral metabolism in CKD, reflecting the combined burden of hyperphosphatemia and calcium imbalance that drives vascular and soft-tissue calcification [5]. Higher Ca×P values have been consistently associated with increased cardiovascular morbidity and mortality in adult dialysis cohorts, supporting guideline recommendations to maintain Ca×P below approximately 55 mg^2/dL^2 when possible.

In addition to its calcification and mortality implications, Ca×P has emerged as a potential biomarker of musculoskeletal (MSK) risk. In adult patients with CKD, chronic MSK pain was independently associated with higher Ca×P after adjustment for comorbidities and other biochemical variables [20].

A recent pediatric HD study reported that approximately two-thirds of children experienced MSK pain, and multivariable analysis identified Ca×P together with vitamin D level as the strongest contributors to MSK pain, highlighting Ca×P as a clinically relevant surrogate of MSK risk in this population [20].

Given this background, we selected Ca×P as a pragmatic laboratory marker to capture potential mineral metabolism effects of intradialytic exercise and to assess its potential link to MSK risk [5]. In our study, mean Ca×P remained within a range close to guideline targets at both time points and showed a small, non-significant increase after eight weeks of exercise (52.7±17.71 to 59.43±8.43 mg^2/dL^2; P=0.36), with wide CI that encompass both modest improvement and worsening. The effect-size estimate (Cohen's $d \approx 0.5$) suggests at most a small-to-moderate change, but the very small sample size and variability in baseline Ca×P preclude firm conclusions regarding the direction or magnitude of any true effect.

These findings are consistent with adult trials in which intradialytic exercise produced variable and generally modest changes in calcium, phosphate, and PTH, often without clear sustained reductions in Ca×P, especially when baseline mineral control was already acceptable [16]. Importantly, we did not directly measure MSK pain, physical function, or bone density; therefore, any inference linking Ca×P trajectories to MSK outcomes in our cohort must remain speculative [16]. Nevertheless, the high prevalence and prognostic significance of MSK manifestations in CKD and dialysis populations underscore the need to incorporate standardized MSK outcome measures, such as pain scales, functional questionnaires, and imaging—into future pediatric exercise trials alongside Ca×P and other mineral biomarkers [6].

Such studies could clarify whether exercise-induced changes in Ca×P or related mineral parameters translate into tangible improvements in MSK symptoms, quality of life, and long-term skeletal health in children with HD [5].

Several strengths of this study merit consideration, including the prospective design, detailed characterization of infectious events using standardized criteria, and the use of a structured, supervised intradialytic exercise protocol tailored to pediatric patients [21].

However, the limitations are substantial and mainly related to feasibility and sample size; only five children completed the intervention, which severely limits the statistical power and generalizability of the findings. The single-center, single-arm pre–post design without a concurrent control group precludes causal inference and makes it difficult to disentangle exercise effects from temporal trends, seasonal variation in infections, or changes in dialysis care [16]. Additionally, we did not systematically assess adherence outside supervised sessions, nor did we collect comprehensive data on concomitant changes in medication or dialysis prescription that might influence Ca×P or infection risk [7].

In summary, this pilot study suggests that an eight-week combined intradialytic exercise program is feasible and appears safe for children undergoing HD, without increasing infection rates or destabilizing Ca×P control. However, it was underpowered to demonstrate significant benefits on these outcomes [7]. Future multicenter randomized controlled trials with larger pediatric samples, longer follow-up periods, and comprehensive assessments of infections, Ca×P and other mineral parameters, and MSK outcomes are needed to determine whether structured intradialytic exercise can meaningfully reduce infectious morbidity and MSK risk in this vulnerable population [6].

Conclusion

This pilot study demonstrates that an 8-week combined intradialytic exercise program is feasible and safe for children undergoing maintenance HD. It did not increase infection rates or destabilize Ca×P control. These findings support integrating supervised intradialytic exercise into pediatric HD care and strongly justify larger, multicenter randomized controlled trials with longer follow-up to determine its effects on infectious morbidity and mineral-bone health in this vulnerable population.

Ethical Considerations

Compliance with ethical guidelines

Ethical approval for this study was obtained from the Ethics Committee of the Faculty of Sports Sciences, University of Tehran (Code: IR.UT.SPORT.REC.1403.058), and the study was registered in the Iranian Registry of Clinical Trials (IRCT) (Code: IRCT20241012063340N1).

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Authors' contributions

All authors contributed equally to the conception and design of the study, data collection and analysis, interpretation of the results, and manuscript drafting. Each author approved the submission of the final version of the manuscript.

Conflict of interest

The authors declared no conflict of interest.

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