

# Intradialytic resistance training: an effective and easy-to-execute strategy

Treinamento resistido intradialítico: uma estratégia eficaz e de fácil execução  
Intradialytic resistance training: an effective and easy-to-execute strategy

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## ABSTRACT

Chronic kidney disease (CKD) alters the morphology and function of skeletal muscles, thereby decreasing patient physical capacity (PC) and quality of life (QoL). Intradialytic resistance training (IRT) is a pragmatic tool used to attenuate these complications. However, IRT has not been strongly adopted in nephrology care centers. This study aimed to assess the efficacy and safety of a low-cost, easy-to-use IRT protocol. **Methods:** The study enrolled 43 patients ( $52.8 \pm 13.85$  years) on HD for five to 300 months followed from April 2014 to July 2017. The efficacy of IRT was assessed based on PC - derived from muscle strength (MS) and preferred walking speed (PWS) - and QoL. The occurrence of adverse events was used as a measure of safety. The IRT protocol consisted of exercises of moderate to high intensity for the main muscle groups performed three times a week. **Results:** The mean follow-up time was  $9.3 \pm 3.24$  months, for a total of 4,374 sessions of IRT. Compliance to the protocol was  $96.5 \pm 2.90\%$ , and patients presented significant improvements in MS (from  $27.3 \pm 11.58$  Kgf to  $34.8 \pm 10.77$  Kgf) and PWS (from  $0.99 \pm 0.29$  m/s to  $1.26 \pm 0.22$  m/s). Physical and emotional components of QoL also increased significantly. **Conclusion:** IRT led to significant increases in PC and higher scores in all domains of QoL. Important adverse events were not observed during intradialytic resistance training.

**Keywords:** Resistance Training; Renal Insufficiency; Renal Dialysis; Quality of Life; Muscle Strength.

## RESUMO

A doença renal crônica (DRC) promove alterações morfofuncionais dos músculos esqueléticos, gerando redução da capacidade físico-funcional (CF) e pior qualidade de vida (QV). O treinamento resistido intradialítico (TRI) é considerado uma ação pragmática para atenuar tais complicações. Contudo, nota-se baixa inserção do TRI nos centros de tratamento em nefrologia. O objetivo deste estudo foi avaliar a eficácia e a segurança de uma proposta metodológica de TRI de fácil execução e de baixo custo. **Métodos:** 43 pacientes ( $52,8 \pm 13,85$  anos), com tempo em HD entre cinco e 300 meses, foram acompanhados entre abril de 2014 e julho de 2017. A eficácia do TRI foi mensurada pela CF, avaliada pela força muscular (FM) e pela velocidade de caminhada usual (VCU) e pela QV. Como critério de segurança adotou-se a ocorrência de intercorrências clínicas. O protocolo de TRI consistiu em exercícios de moderada a alta intensidade para os principais grupos musculares, realizados três vezes por semana. **Resultados:** o tempo médio de acompanhamento foi de  $9,3 \pm 3,24$  meses, totalizando 4.374 sessões de TRI. A aderência ao protocolo foi de  $96,5 \pm 2,90$ , e os pacientes apresentaram melhora significativa da FM (de  $27,3 \pm 11,58$  Kgf para  $34,8 \pm 10,77$  Kgf) e da VCU (de  $0,99 \pm 0,29$  m/s para  $1,26 \pm 0,22$  m/s). Quanto à QV, tanto os domínios do componente físico quanto do emocional aumentaram significativamente. **Conclusão:** o TRI promoveu aumento significativo da CF e melhora de todos os domínios da QV, e não foram observadas intercorrências importantes com a realização dos exercícios intradialíticos.

**Palavras-chave:** Treinamento de Resistência; Insuficiência Renal; Diálise Renal; Qualidade de Vida; Força Muscular.



## INTRODUCTION

Individuals with chronic kidney disease (CKD) suffer from alterations in the morphology and function of skeletal muscles, which translate into weakness and gradual decreases in physical capacity (PC) and quality of life (QoL).<sup>1,2</sup> In recent years, some of the guidelines published in nephrology - the K/DOQI in particular - have advocated the introduction of exercise training as a measure to attenuate complications and decrease the occurrence of adverse outcomes such as loss of autonomy, increased risk of falls, endocrine and metabolic disorders, and higher hospitalization rates mainly for cardiovascular events.<sup>3-6</sup> Many authors have written about the benefits of exercise training - and specifically aerobic exercises - at improving PC and QoL in patients with CKD.<sup>7,8</sup> Studies carried out by our group revealed that aerobic exercises were safe and produced increases in  $\text{VO}_2$  max and better PC and QoL.<sup>9,10</sup> Although beneficial, intradialytic resistance training (IRT) still faces a few obstacles in attaining greater levels of acceptance in clinical practice on account of the high costs associated with procuring and maintaining exercise equipment and the need to modify the room in which equipment is installed. Additionally, patients with CKD are often unable to bear the volume and intensity required for effective aerobic training for reasons such as low levels of cardiorespiratory fitness; lower limb bone, muscle, and joint limitations; and femoral dialysis catheters. Therefore, few dialysis centers in Brazil offer IRT.

Few studies have looked into moderate to high intensity IRT, a method with great potential for improving muscle strength (MS) and PC.<sup>11,12</sup> Headley et al.<sup>13</sup> studied patients on a 12-week low-intensity IRT protocol and observed a 13% increase in the strength of knee extensor muscles. Kirkman et al.<sup>14</sup> corroborated these findings as they analyzed a group of patients on a 12-week IRT program of moderate-to-high intensity using sophisticated training equipment. The authors reported a 60% increase in the strength of a specific muscle group in 23 patients. Preliminary data from our service show that MS, preferred walking speed (PWS), and QoL improved after three months of IRT using low cost equipment (ankle weights and dumbbells). Although results are promising, questions over the safety of IRT and the lack of knowledge from health care workers still seem to pose barriers

to a wider adoption of exercise training programs in nephrology centers.<sup>15,16</sup>

This study aimed to assess the efficacy and safety of a moderate-to-high intensity, easy-to-execute and affordable intradialytic resistance training protocol.

## METHODS

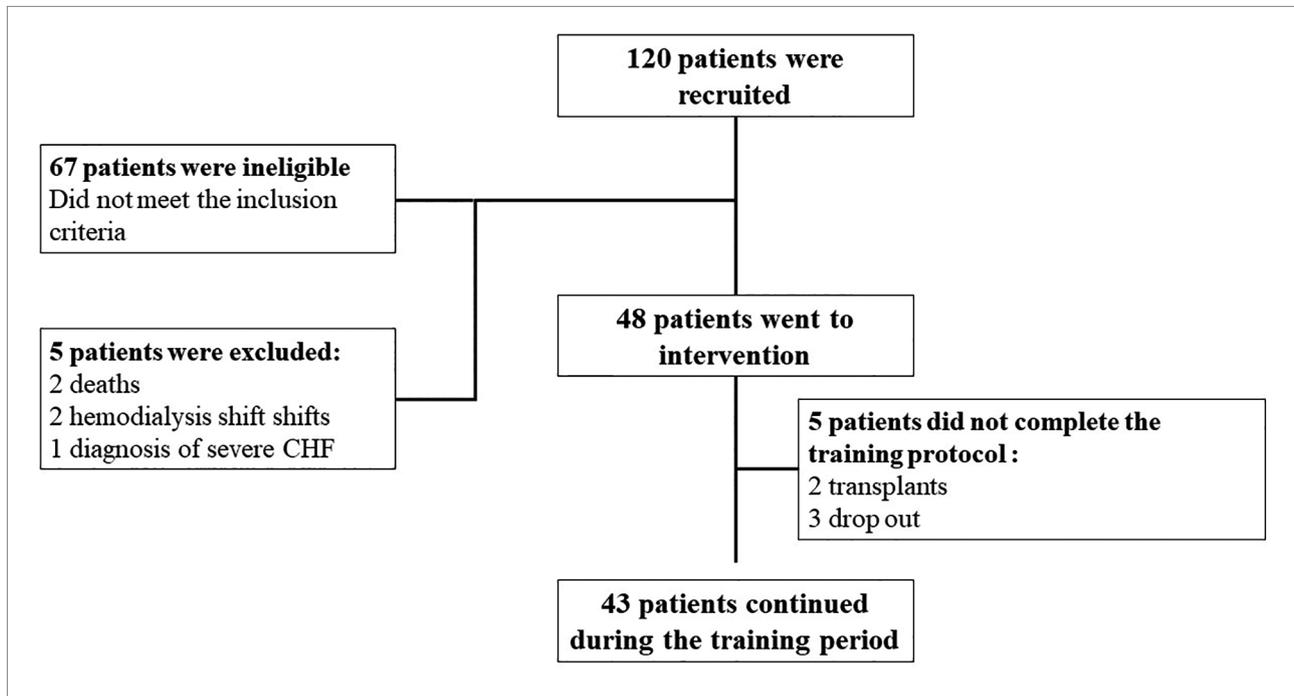
This prospective controlled study with supervised intervention was carried out from April 2014 to July 2017. The Research Ethics Committee of the Hospital Universitário da Universidade Federal de Juiz de Fora approved the study (opinion 375.003).

## PATIENTS

Adult patients of both sexes on hemodialysis for at least three months were included in the study. Information concerning the assessment and training protocols were shared with the patients, who voluntarily signed an informed consent term approved by the Research Ethics Committee of the Hospital Universitário da Universidade Federal de Juiz de Fora (CAAE: 20145613.4.0000.5133; no. 375.003).

The following exclusion criteria were applied: hypoalbuminemia (serum albumin < 3 g/dL), fasting glucose > 300 mg/dL, unstable angina, heart arrhythmia, decompensated heart failure, uncontrolled hypertension defined as systolic blood pressure (SBP)  $\geq$  200 mmHg and/or diastolic blood pressure (DBP)  $\geq$  120 mmHg, uremic pericarditis, severe lung disease, acute systemic infection, severe renal osteodystrophy, and musculoskeletal disorders preventing the patients from performing the exercises. Figure 1 shows the patient enrollment workflow.

Before initiating the physical training program, all patients underwent cardiologic, anthropometric, and PC assessment. Cardiologic assessment included an interview, physical examination, and exercise tests to detect possible physical effort-induced cardiovascular disorders. In anthropometric evaluation, the body mass index (BMI) was calculated based on the dry weight. PC was analyzed based on the hand grip strength test, the 30-second chair stand test, and the 15-foot walk test to find the PWS. All tests were carried out on days between dialysis sessions. The Medical Outcomes Study 36-Item Short Form Health Survey (SF-36) was applied as an interview to assess patient QoL. The SF-36 comprises 36 items in the

**Figure 1.** Patient enrollment workflow

following scales: physical functioning, role-physical, bodily pain, general health, vitality, social functioning, role-emotional, and mental health. For each of the scales patients can score from 0 (worst QoL) to 100 (best QoL). Demographic data, clinical, and workup parameters were gathered from the patients' charts and HD session records.

The effect of moderate-to-high intensity IRT on MS, PC, and QoL was investigated as a primary endpoint. The secondary endpoint was the impact of IRT on the quality of dialysis analyzed via the Kt/V. This parameter was calculated based on the ratio between the product of the dialyzer clearance of urea (K) and dialysis time (t) over the volume of distribution of urea clearance (V).

#### EXPERIMENTAL PROTOCOL

The patients had resting blood pressure and heart rate measured before the start of the IRT sessions. Diabetic individuals also had their capillary blood glucose checked. With safety in mind, patients were allowed to start IRT sessions as long as the SBP ranged between 110 and 160 mmHg and/or DBP were between 50 and 100 mmHg and if their resting heart rate were between 50 and 100 bpm. The capillary blood glucose of diabetic patients had to be between 100 and 250 mg/dL.

Physical education professionals supervised the patients throughout the IRT sessions three times a week. The training sessions were carried out during the first two hours of HD and lasted for approximately 50 minutes. The proposed IRT (Figure 2) consisted of exercises for the main muscle groups (dorsal muscles: unilateral standing row; pectoral muscles: flat bench press; deltoid muscles: seated shoulder press; quadriceps: knee extension; hamstrings: knee flexion; calf muscle: plantar flexion in an orthostatic position; brachial triceps: unilateral French press; brachial biceps: unilateral curl). In order to perform the exercises in an orthostatic position, the patients were aided by a physical educator to stabilize their arms with the arteriovenous fistula (Figure 3).

In the first week of the protocol (familiarization stage) the patients were requested to perform only one set of 10 to 15 repetitions for each of the exercises. In the second week they moved up to two sets of 10 to 15 repetitions. From the third week onwards they performed three sets of 10 to 15 repetitions. The Borg rating of perceived exertion (RPE) was used to determine and manage effort intensity in all stages of the protocol.<sup>17</sup> Individuals were asked, in plain terms, to assess the training load considering central (e.g.: lung

**Figure 2.** Initial proposal of a resistance training protocol for patients on hemodialysis. Notes: (a) bilateral knee extension with ankle weights; (b) unilateral shoulder abduction and elbow extension with dumbbells (shoulder development); (c) unilateral elbow flexion with dumbbells (biceps curl); (d) alternating knee flexion with ankle weights; (e) bilateral plantar flexion (free calf); (f) unilateral elbow extension with dumbbells (French press); (g) unilateral shoulder extension and elbow flexion with dumbbells (row).



**Figure 3.** Technique used by a physical educator to support the arteriovenous fistula arm of a patient on hemodialysis during standing resistance training.



ventilation) and peripheral factors (muscles and joints). After assessing the level of effort, the patients were asked to assign a score to their perceived exertion on a scale ranging from 6 to 20, in which 6 meant less exertion and 20 the highest possible level of exertion. The enrolled patients performed exercises scored between 15 and 17, the equivalent of “strong” and “very strong” perceived effort. At the end of each set and exercise, the patients were asked about their RPE. If they scored outside the study range, the load was adjusted by about 5% to either increase or decrease it. In order to manage intensity, patients performing all three sets with 15 repetitions had the load readjusted by about 5% the following session. In all stages of the protocol patients were given 90 to 120 seconds to rest between sets and exercises. In order to avoid early muscle fatigue, the exercises were performed alternating between segments as per the guidelines set out by the American College of Sports Medicine.<sup>18</sup>

## RESULTS

A total of 120 patients were initially selected, but 48 ended up being enrolled (40%) and 43 stayed until the end. The mean age of the included patients was  $52.8 \pm 13.85$  years, as characteristically seen in populations on HD. Most were males, and time on HD ranged from five to 300 months. Demographic and clinical variables at the start of the protocol are described on Table 1.

The total time of intervention was 39 months, with a mean follow-up time of  $9.3 \pm 3.24$  months and a total of 4,374 individual IRT sessions. Compliance to protocol was  $96.5 \pm 2.90\%$ , and only 0.80% of the sessions were not carried out for reasons such as uncontrolled blood pressure, pain or mismatches with the HD schedule. No significant complications were observed during the IRT sessions. Only one case of a hematoma associated with the arteriovenous fistula was recorded due to patient neglect.

The load for all exercises was gradually increased throughout the weeks of training. The loads used in the first and last week of the program were statistically different ( $p < 0.001$ ). Load progression was similar in all exercises and ranged from 180% to 440% of the initial load (Figure 4). Consequently, MS increased significantly from  $27.3 \pm 11.58$  Kgf to  $34.8 \pm 10.77$  Kgf ( $p = 0.004$ ). In addition to increasing the training load, patients improved PC as a function of the PWS, which grew from an initial  $0.99 \pm 0.29$  m/s to  $1.26 \pm 0.22$  m/s ( $p = 0.0003$ ).

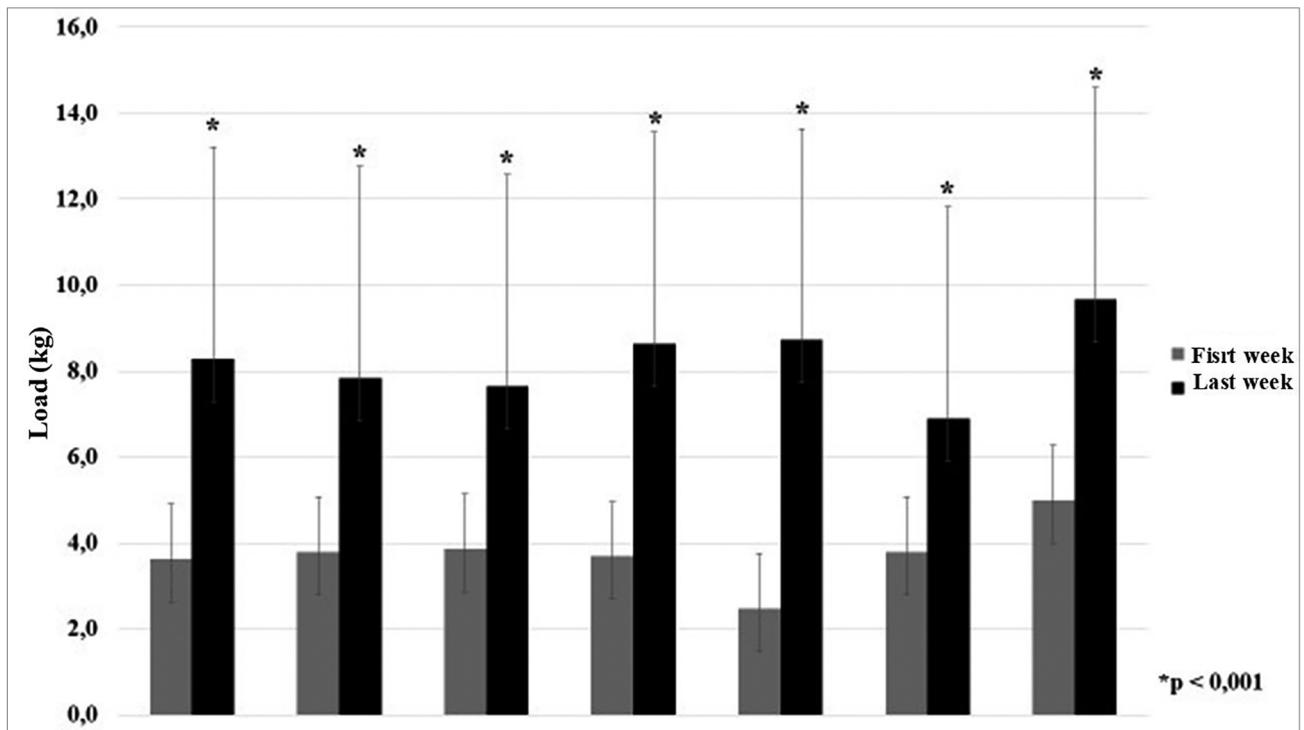
QoL also improved when the first and last weeks of training were compared, both in the domains associated with physical and emotional elements (Figure 5).

At the end of the follow-up period, a non-significant improvement was seen in the quality of dialysis assessed by Kt/V, which moved from  $1.4 \pm 0.50$  to  $1.6 \pm 0.36$ .

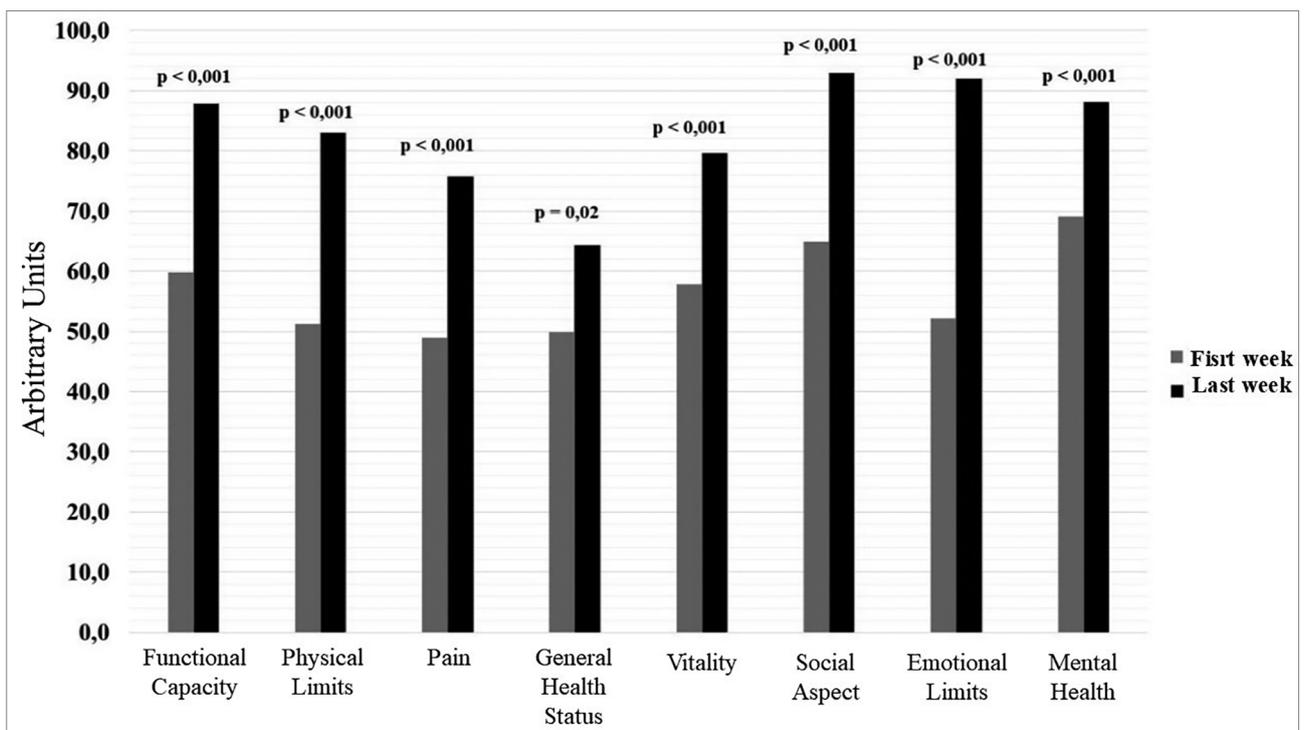
**TABLE 1** DEMOGRAPHIC AND CLINICAL FINDINGS OF THE STUDY POPULATION

Variable	Total (n = 43)
Sex [male: female; n (%)]	37:16 (70/30%)
Age [years; mean (SD)]	52.8 (13.85)
Time on hemodialysis [months; median (IQR)]	36 (17 - 105)
Kt/V [mean (SD)]	1.47 (0.50)
Body mass index [kg/m <sup>2</sup> ; mean (SD)]	26.0 (7.40)
Etiology of CKD [n (%)]	
Hypertensive nephrosclerosis	29 (54.7%)
Glomerulonephritis	8 (15.1%)
Diabetic kidney disease	8 (15.1%)
Polycystic kidney disease	1 (1.9%)
Other/unknown	3 (5.7%)

**Figure 4.** Gradual exercise load increases: initial vs. final load. Notes: 1: knee extension; 2: development; 3: elbow flexion; 4: knee flexion; 5: plantar flexion; 6: elbow extension; 7: unilateral row; \* significant difference between initial and final load.



**Figure 5.** Comparison between initial and final scores in the assessed quality-of-life scales.



## DISCUSSION

This study presented data on the efficacy and safety of an individualized resistance training protocol supervised by physical educators offered to patients during hemodialysis sessions. The training model used in this study was based on the use of low cost materials and produced increases in MS, PC, and QoL improvements. The protocol was well accepted and tolerated by the patients, and no significant adverse events were recorded, which characterized it as a safe, affordable, and easy-to-execute method.

Although technological advancements related to improved quality of dialysis and comorbidity management have been implemented in recent years, patients with CKD still present with lower levels of MS and PC when compared to the population in general. Several studies have shown that exercise training may positively impact these variables.<sup>7,8</sup> Although most studies were conducted using aerobic exercises alone or combined with low intensity resistance training, recent evidence indicates that the benefits of moderate and high intensity resistance training may be superior at increasing MS.

An increase of 45% in MS was seen in our study, as similarly reported by Molsted et al.<sup>19</sup> and Kirkman et al.,<sup>14</sup> who reported respective increases of 46% and 60% after high intensity training using sophisticated equipment. Chen et al.<sup>20</sup> and Chan et al.<sup>21</sup> did not report significant increases in MS, possibly because in their studies the patients were offered low to moderate intensity exercise training.

In addition to serving as an indicator of global health status, PWS is a known marker of PC and a predictor of risk of death for all causes and cardiovascular disease. Individuals with CKD have lower PWS than the general population.<sup>22</sup> Kutner et al.<sup>23</sup> studied 752 patients and noticed that lower PWS was associated with greater risk of death. In our study, initial PWS was low and similar to the values reported by other authors.<sup>24-26</sup> PWS increased significant after exercise training, as also reported by Headley et al.,<sup>13</sup> Bennett et al.,<sup>27</sup> and Anding et al.<sup>28</sup> Johansen et al.<sup>29</sup> and Corrêa et al.<sup>30</sup> did not report significant increases in PWS, possibly because in their studies patients performed low intensity training.

In recent years, the QoL of individuals with CKD has captured the attention of health care workers. CKD of all stages significantly compromises all QoL domains. Despite the advancements achieved in the

treatment of CKD, improving the QoL of patients with this condition is still a challenge in clinical practice. Strategies such as nutritional plans, psychotherapy, and compliance improvements are examples of actions devised to recuperate patient QoL.<sup>4</sup> Various studies have also shown that the lower level of QoL observed in individuals with CKD when compared to the general population is invariably associated with increased morbimortality.<sup>31,32</sup> Other factors that may compromise QoL include decreased MS and PC.<sup>33</sup> The QoL of the patients enrolled in our study increased significantly in physical and emotional domains after the introduction of exercise training. The improvements seen in our study were greater than the improvements reported by Johansen et al.,<sup>29</sup> Bennett et al.,<sup>27</sup> Corrêa et al.,<sup>30</sup> and Rosa et al.,<sup>34</sup> partly on account of continuous supervision by a physical educator and training intensity and length.

With compliance rates close to 95% and interruptions in only 0.8% of the sessions, the results reported in this study were similar to the findings reported by Kirkman et al.<sup>14</sup> and were notably superior when compared to the results described by Headley et al.,<sup>13</sup> DePaul et al.,<sup>25</sup> Nindl et al.,<sup>35</sup> Chen et al.,<sup>20</sup> and 36 Martin-Alemañy et al.<sup>36</sup> Our results and the improved levels of MS, PC, and QoL may be attributed to the exercise protocol implemented during HD sessions, the progressive adjustment of exercise loads in accordance with the guidelines of the American College of Sports Medicine,<sup>18</sup> and supervision by a physical educator.

Exercise training has been tried experimentally with patients with CKD for more than three decades with proven benefits. Nevertheless, the practice is still seen with reserve at nephrology centers. It has been speculated that factors associated with the disease itself - including anemia, fatigue, and exertion intolerance - in addition to fear of clinical complications, unawareness of the benefits of exercise training, lack of training on the delivery of IRT, and low patient motivation act as barriers to the implementation of exercise training programs in kidney centers.<sup>37-39</sup> The concern of health workers with clinical complications happening during physical exercise is valid. However, a meta-analysis published by Cheema et al.<sup>40</sup> found that the risk of adverse events occurring during exercise training is low. Accordingly, our study had only one case of a patient with a hematoma in the arm of the arteriovenous fistula after an exercise session, an adverse event not directly related to IRT.

On account of its physiological and methodological characteristics, IRT allows patients to pause between exercise sets and use different muscle groups, thus minimizing fatigue and exercise intolerance. Besides, HD sessions become less tedious and some patients find additional motivation and relief in exercises while undergoing hemodialysis. The IRT protocol described in this paper requires low cost materials (dumbbells and ankle weights) and no changes to HD rooms, as is the case of exercise programs delivered on cycle ergometers.

A recent meta-analysis showed that the combination of resistance and aerobic training produced superior effects on PC and QoL when compared to each training mode done separately.<sup>41</sup> Further clinical trials comparing the effectiveness of aerobic and resistance training at different levels of intensity, including a scenario in which patients do exercises at home, may contribute to the optimization of exercise training for patients with CKD on renal replacement therapy.

## CONCLUSION

Supervised IRT significantly increased MS and PC and improved the overall QoL of patients with CKD. The easy-to-execute and affordable protocol described in this paper was effective and did not correlate with significant adverse events, which opens the doors to the implementation of this mode of conservative management for individuals with CKD as recommended in recent nephrology guidelines.

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## REFERENCES

- Mansur HN, Damasceno VO, Bastos MG. Prevalência da fragilidade entre os pacientes com doença renal crônica em tratamento conservador e em diálise. *J Bras Nefrol* 2012;34:153-60.
- Tamura MK, Covinsky KE, Chertow GM, Yaffe K, Landefeld CS, McCulloch CE. Functional Status of Elderly Adults before and after Initiation of Dialysis. *N Engl J Med* 2009;361:1539-47.
- Jaar BG, Chang A, Plantinga L. Can we improve quality of life of patients on dialysis? *Clin J Am Soc Nephrol* 2013;8:1-4.
- Feroze U, Noori N, Kovesdy CP, Molnar MZ, Martin DJ, Reina-Patton A, et al. Quality-of-life and mortality in hemodialysis patients: roles of race and nutritional status. *Clin J Am Soc Nephrol* 2011;6:1100-11.
- National Kidney Foundation. KDOQI Clinical Practice Guideline for Hemodialysis Adequacy: 2015 Update. *Am J Kidney Dis* 2015;66:884-930.
- Smart NA, Williams D, Levinger I, Selig S, Howden E, Coombes JS, et al. Exercise & Sports Science Australia (ESSA) position statement on exercise and chronic kidney disease. *J Sci Med Sport* 2013;16:406-11.
- Heiwe S, Jacson SH. Exercise for adults with chronic kidney disease. *Cochrane Database Syst Rev* 2014;(10):3236-40.
- Sheng K, Zhang P, Chen L, Cheng J, Wu C, Chen J. Intradialytic exercise in hemodialysis patients: a systematic review and meta-analysis. *Am J Nephrol* 2014;40:478-90.
- Reboredo Mde M, Henrique DM, Faria Rde S, Chaoubah A, Bastos MG, de Paula RB. Exercise training during hemodialysis reduces blood pressure and increases physical functioning and quality of life. *Artif Organs* 2010;34:586-93.
- Reboredo MM, Neder JA, Pinheiro BV, Henrique DM, Lovisi JC, Paula RB. Intra-dialytic training accelerates oxygen uptake kinetics in hemodialysis patients. *Eur J Prev Cardiol* 2015;22:912-9.
- Rhee CM, Kalantar-Zadeth K. Resistance exercise: an effective strategy to reverse muscle wasting in hemodialysis patients? *J Cachexia Sarcopenia Muscle* 2014;5:177-80.
- Bessa B, de Oliveira Leal V, Moraes C, Barboza J, Fouque D, Mafra D. Resistance training in hemodialysis patients: a review. *Rehabil Nurs* 2015;40:111-26.
- Headley S, Germain M, Mailloux P, Mulhern J, Ashworth B, Burrell J, et al. Resistance training improves strength and functional measures in patients with end-stage renal disease. *Am J Kidney Dis* 2002;40:355-64.
- Kirkman DL, Mullins P, Junglee NA, Kumwenda M, Jibani MM, Macdonald JH. Anabolic exercise in hemodialysis patients: a randomised controlled pilot study. *J Cachexia Sarcopenia Muscle* 2014;5:199-207.
- Thompson S, Clark A, Molzahn A, Klarenbach S, Tonelli M. Increasing the uptake of exercise programs in the dialysis unit: a protocol for a realist synthesis. *Syst Rev* 2016;5:67.
- Najas CS, Pissulin FDM, Pacagnelli FL, Betônico GN, Almeida IC, Neder JA. Segurança e Eficácia do Treinamento Físico na Insuficiência Renal Crônica. *Rev Bras Med Esporte* 2009;15:384-8.
- Borg GA. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc* 1982;14:377-81.
- American College of Sports Medicine. American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. *Med Sci Sports Exerc* 2009;41:687-708.
- Molsted S, Harrison AP, Eidemak I, Andersen JL. The effects of high load strength training with protein- or nonprotein-containing nutritional supplementation in patients undergoing dialysis. *J Ren Nutr* 2013;23:132-40.
- Chen JLT, Godfrey S, Ng TT, Moorthi R, Liangos O, Ruthazer R, et al. Effect of intra-dialytic, low-intensity strength training on functional capacity in adult haemodialysis patients: a randomized pilot trial. *Nephrol Dial Transplant* 2010;25:1936-43.
- Chan D, Cheema BS. Progressive Resistance Training in End-Stage Renal Disease: Systematic Review. *Am J Nephrol* 2016;44:32-45.
- Torino C, Manfredini F, Bolognani D, Aucella F, Baggetta R, Barillà A et al.; EXCITE Working Group. Physical performance and clinical outcomes in dialysis patients: a secondary analysis of the EXCITE trial. *Kidney Blood Press Res* 2014;39:205-11.
- Kutner NG, Zhang R, Huang Y, Painter P. Gait Speed and Mortality, Hospitalization, and Functional Status Change Among Hemodialysis Patients: A US Renal Data System Special Study. *Am J Kidney Dis* 2015;66:297-304.
- Cheema B, Abas H, Smith B, O'Sullivan A, Chan M, Patwardhan A, et al. Progressive exercise for anabolism in kidney disease (PEAK): a randomized, controlled trial of resistance training during hemodialysis. *J Am Soc Nephrol* 2007;18:1594-601.

25. DePaul V, Moreland J, Eager T, Clase CM. The effectiveness of aerobic and muscle strength training in patients receiving hemodialysis and EPO: a randomized controlled trial. *Am J Kidney Dis* 2002;40:1219-29.
26. Painter P, Carlson L, Carey S, Paul SM, Myll J. Low-functioning hemodialysis patients improve with exercise training. *Am J Kidney Dis* 2000;36:600-8.
27. Bennett PN, Breugelmans L, Agius M, Simpson-Gore K, Barnard B. A haemodialysis exercise programme using novel exercise equipment: a pilot study. *J Ren Care* 2007;33:153-8.
28. Anding K, Bär T, Trojniak-Hennig J, Kuchinke S, Krause R, Rost JM, et al. A structured exercise programme during haemodialysis for patients with chronic kidney disease: clinical benefit and long-term adherence. *BMJ Open* 2015;5:e008709.
29. Johansen KL, Painter PL, Sakkas GK, Gordon P, Doyle J, Shubert T. Effects of resistance exercise training and nandrolone decanoate on body composition and muscle function among patients who receive hemodialysis: A randomized, controlled trial. *J Am Soc Nephrol* 2006;17:2307-14.
30. Corrêa LB, Oliveira RN, Cantareli F, Cunha LS. Efeito do Treinamento Muscular Periférico na Capacidade Funcional e Qualidade de Vida nos Pacientes em Hemodiálise. *J Bras Nefrol* 2009;31:18-24.
31. Mujais SK, Story K, Brouillette J, Takano T, Soroka S, Franek C, et al. Health-related quality of life in CKD patients: correlates and evolution over time. *Clin J Am Soc Nephrol* 2009;4:1293-301.
32. Finkelstein FO, Wuerth D, Finkelstein SH. Health related quality of life and the CKD patient: challenges for the nephrology community. *Kidney Int* 2009;76:946-52.
33. van Loon IN, Bots ML, Boereboom FTJ, Grooteman MPC, Blankestijn PJ, van den Dorpel MA, et al. Quality of life as indicator of poor outcome in hemodialysis: relation with mortality in different age groups. *BMC Nephrol* 2017;18:217.
34. Rosa CSDC, Nishimoto DY, Souza GDE, Ramirez AP, Carletti CO, Daibem CGL, et al. Effect of continuous progressive resistance training during hemodialysis on body composition, physical function and quality of life in end-stage renal disease patients: a randomized controlled trial. *Clin Rehabil* 2018;32:899-908.
35. Nindl BC, Headley SA, Tuckow AP, Pandorf CE, Diamandi A, Khosravi MJ, et al. IGF-I system responses during 12 weeks of resistance training in end-stage renal disease patients. *Growth Horm IGF Res* 2004;14:245-50.
36. Martin-Alemañy G, Valdez-Ortiz R, Olvera-Soto G, Gomez-Guerrero I, Aguire-Esquivel G, Cantu-Quintanilla G, et al. The effects of resistance exercise and oral nutritional supplementation during hemodialysis on indicators of nutritional status and quality of life. *Nephrol Dial Transplant* 2016;31:1712-20.
37. Fiaccadoria E, Sabatino A, Schito F, Angella F, Malagoli M, Tucci M, et al. Barriers to physical activity in chronic hemodialysis patients: a single-center pilot study in an Italian dialysis facility. *Kidney Blood Press Res* 2014;39:169-75.
38. Clarke AL, Young HML, Hull KL, Hudson N, Burton JO, Smith AC. Motivations and barriers to exercise in chronic kidney disease: a qualitative study. *Nephrol Dial Transplant* 2015;30:1885-92.
39. Hannan M, Bronas UG. Barriers to exercise for patients with renal disease: an integrative review. *J Nephrol* 2017;30:729-41.
40. Cheema BS, Chan D, Fahey P, Atlantis E. Effect of progressive resistance training on measures of skeletal muscle hypertrophy, muscular strength and health-related quality of life in patients with chronic kidney disease: a systematic review and meta-analysis. *Sports Med* 2014;44:1125-38.
41. Gomes Neto M, Lacerda FFR, Lopes AA, Martinez BP, Saquetto MB. Intradialytic exercise training modalities on physical functioning and health-related quality of life in patients undergoing maintenance hemodialysis: systematic review and meta-analysis. *Clin Rehabil* 2018;32:1189-202.