Original research

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Pulmonary function and ventilatory capacity in hemodialysis patients according to exposure to intra-dialysis physical training

Función pulmonar y capacidad ventilatoria en pacientes hemodializados según exposición a entrenamiento físico intradiálisis

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Abstract

Introduction: The chronic kidney disease (CKD) is an irreversible progressive process which leads to a terminal state, where patients need permanent dialysis or even a transplant. It has been shown that the lung function and ventilatory capacity are compromised in these patients, increasing the alteration with exposure to hemodialysis and sedentarism.

Objective: To compare the lung function and ventilatory capacity of hemodialysis patients, according to exposure to intradialysis physical training.

Material and Methods: Study of quantitative type, not experimental, descriptive and transverse. The study population included 12 ambulatory patients between 40 and 80 years old, undergoing hemodialysis with arteriovenous fistula in the dialysis unit of Valdivia's Central Hospital, and who obtained more than 24 points in the Minimental Test. The statistical analysis was performed with the SPSS program (version 11.5 for Windows) and the level of statistical significance through the Wilcoxon and Mann-Whitney test ($p<0.05$).

Results: The comparison of the initial and final pimometry in patients with and without physical training did not show a statistically significant difference ($p>0.05$), however it was observed that the subjects exposed to physical training have higher values in the initial and final maximum inspiratory pressure compared to those who have not been trained.

Conclusion: Intradialysis physical training causes a positive effect on the respiratory system. The subjects submitted to hemodialysis tend to present under predicted values in both lung function and ventilatory capacity, being mostly affected with aging and time of exposure to hemodialysis.

Keywords: Renal dialysis, renal insufficiency, chronic, exercise therapy, diagnostic techniques, respiratory system.
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Resumen

Introducción: la enfermedad renal crónica es un proceso progresivo e irreversible; con frecuencia lleva a un estado terminal, donde los pacientes necesitan de diálisis o trasplante. Se ha demostrado que la función pulmonar y la capacidad ventilatoria se ven comprometidas en estos pacientes, y se incrementan con la exposición a hemodiálisis y el sedentarismo.

Objetivo: comparar la función pulmonar y la capacidad ventilatoria de pacientes hemodializados, según exposición a entrenamiento físico intradiálisis.

Materiales y métodos: estudio de tipo cuantitativo, no experimental, descriptivo y transversal; la población de estudio comprendió 12 pacientes hemodializados mediante fístula arteriovenosa, entre 40 y 80 años de edad, en la unidad de diálisis del Hospital Base de Valdivia y que obtuvieron más de 24 puntos en el test Minimental. El análisis estadístico se realizó con el programa SPSS (versión 11.5 para Windows) y el nivel de significancia estadística a través de la prueba de Wilcoxon y Mann-Whitney ($p<0,05$).

Resultados: la comparación de la pimometría inicial y final en los pacientes con y sin entrenamiento kinésico no mostró una diferencia estadísticamente significativa ($p>0,05$); sin embargo, se observó que los sujetos sometidos a entrenamiento kinésico presentan mayores valores en la presión inspiratoria máxima inicial y final en comparación con aquellos que no han sido entrenados.

Conclusión: el entrenamiento físico intradiálisis provoca un efecto positivo en el sistema respiratorio. Los sujetos sometidos a hemodiálisis tienden a presentar valores bajo el predicho tanto en función pulmonar como en capacidad ventilatoria, siendo mayormente afectados con el envejecimiento y el tiempo de exposición a hemodiálisis.

Palabras clave: diálisis renal, insuficiencia renal crónica, terapia por ejercicio, técnicas de diagnóstico del sistema respiratorio.

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Introduction

Chronic kidney disease (CKD) is the presence of alterations in kidney structure or function for at least three months and with implications for health.[1] The diagnostic criteria for CKD are the so-called markers of kidney damage or a reduction in glomerular filtration rate (GFR) below 60 ml/min/1.73 m². CKD is a harmful and expensive disease, associated with extremely high morbidity and mortality even in the earliest stages.[2] Diabetes is one of the leading causes of CKD worldwide. It has been estimated that it affects around 425 million people in the world, and it has been projected that it will increase to more than 629 million people by the year 2045. More than 40% of people with diabetes develop CKD, including a significant number who develop end-stage CKD, requiring dialysis and transplantation.[3]

In Chile, the number of patients undergoing HD has experienced a growth greater than 30-fold in the last 30 years, reaching until the year 2018 a prevalence of 1264 patients per million inhabitants, which is higher than the Latin American average.[4]

The lungs can be seriously damaged due to CKD; as GFR decreases, pulmonary edema and respiratory muscle dysfunction become more common due to the fluid retention and cardiovascular, metabolic, and endocrine alterations. However, the evaluation of lung function is not a routine clinical practice.[5] Treatment with HD causes a series of consequences in all systems, causing fatigue and muscle weakness as common symptoms in these patients, which ultimately alter their quality of life.[6] From the ventilatory point of view, it has been observed that the values of the maximum inspiratory pressure (MIP) and the maximum expiratory pressure (MEP) in dialyzed patients are lower than those predicted according to age and gender.[7] Some studies have suggested that there is a decrease in the values of forced expiratory volume in the first second (FEV1) and forced vital capacity (FVC), reflecting a deterioration in lung capacity.[7,8] From the point of view of physical therapy, the main interventions performed in these patients are aerobic work and strength/resistance work of the muscles of the lower limbs, which have been shown to improve hemodialysis adequacy, exercise capacity, depression and quality of life mainly.[9]

Given the foregoing, the following research question arises: How is the lung function and ventilatory capacity of hemodialysis patients according to exposure to intradialysis physical training? The general objective of the research is to compare the lung function and the ventilatory capacity of hemodialysis patients according to exposure to intradialysis physical training. On the other hand, the specific objectives are to describe the pulmonary function parameters prior to the hemodialysis session, to analyze the parameters of the inspiratory muscle strength pre- and post-hemodialysis session, and to compare the maximum inspiratory strength pre- and post-hemodialysis session in patients with and without kinesic training.

Therefore, the hypothesis of this research is that hemodialysis patients undergoing intradialysis kinesic training have better lung function and ventilatory capacity than those who have not undergone kinetic training.

Materials and methods

A quantitative, non-experimental, descriptive and cross-sectional study, which compared the lung function and ventilatory capacity of two groups, one made up of hemodialysis patients undergoing intradialysis physical exercise and the other group consisting of hemodialysis patients who have not been subjected to physical exercise. The variables considered were: exposure to physical exercise, lung function and maximum inspiratory pressure.

The collection of the information was carried out through a census, since the size of the study population consisted of a small number of individuals.

The study population included all outpatients between 40 and 80 years of age who underwent HD with arteriovenous fistula (AVF) in the dialysis unit of the *Hospital Base de Valdivia* (HBV); therefore, the census was carried out with 49 patients, 12 of whom

(7 men and 5 women) were outpatients undergoing a process of HD with AVF for more than 12 months, treated in the dialysis unit of the *Hospital Base de Valdivia* (HBV) and who obtained a score higher than or equal to 24 points in the mental status test «Mini mental state examination». Of the 12 patients, 5 were practicing intradialysis physical exercise.

In addition, patients with a lack of understanding and/or collaboration during the evaluation, with some primary respiratory disorder, and all those who had smoking habits during the last two months were excluded. Through the informed consent, which was signed by the 12 patients, the evaluations to be performed (pimometry and spirometry) were revealed, together with the final objective of the study and its importance for future research. In addition, emphasis was made in that the patient could withdraw when deemed necessary.

Through the review of the clinical record of each patient, the date of admission to the dialysis service and the start of HD treatment with AVF were obtained and, in turn, through an interview, it was established the number of patients subjected to intradialysis physical exercise program, which is conducted by students of the School of Kinesiology of the *Universidad Austral de Chile* (UACh) who develop their clinical practice in the dialysis unit of the HVB, and consists in aerobic exercise performed with a cycle ergometer attached to the dialysis stretcher and exercises of strength/resistance of the lower limbs using free weights or elastic bands.

The different parameters of lung function, either FEV1/FVC, FVC, FEV1 or FEF 25-75%, were obtained through the spirometry assessment based on the protocol of Gutiérrez *et al*.,[10] which was performed by one of the properly trained evaluators. This was carried out during the week, depending on the shift and the schedule of each patient, either on Monday-Wednesday-Friday or on Tuesday-Thursday-Saturday, prior to the HD session. The equipment used for these evaluations was a Datospir Micro C Sibelmed® spirometer.

The ventilatory capacity was determined by the evaluation of the pimometry, based on the technique described by Black and Hyatt.[11] The MIP was assessed before and after hemodialysis by two evaluators; one of them performed the initial pimometry (predialysis) and the other the final pimometry (post-dialysis). For this technique, an aneroid manometer calibrated in cmH_2O (Airlift/Carefore Medical Inc.), an anti-reflux «T» piece, (Nif-Tee®), a nose clip (DHD, USA.), protective filters and reusable mouthpieces with an external diameter of 22 cm (Airlift/Carefore Medical Inc.) were used.

It should be noted that before starting the evaluations considered for this study, the approval of the Research Ethics Committee of the Valdivia Health Service was obtained and the patients received informed consent approved by this entity.

The data analysis was performed through the SPSS (Statistical Package for the Social Sciences) software in its version 11.5 for Windows, summary measures such as mean and standard deviation were determined, and box-and-whisker plots were constructed. The Wilcoxon sign-rank and the Mann-Whitney non-parametric statistical tests were used to establish significant differences. A p-value <0.05 was considered statistically significant.

On the other hand, the spirometric values were compared with the Chilean P5 proposed by Gutiérrez *et al*.,[10] and the pimometry values were compared with the values proposed by Costa *et al*.[12]

Results

The final sample of the study included 12 patients (men 58.3% and women 41.7%) with end-stage CKD belonging to the Dialysis Unit of the *Hospital Base de Valdivia*. Their mean age was 54.2 ± 9.8 and the time of exposure to hemodialysis was 5.0 ± 3.1. 42% of patients were part of an intradialysis exercise program and 58% did not perform any type of exercise.

The pulmonary function parameters (FEV1/FVC, FEV1, FVC, FEF 25-75%) of the patients prior to the HD session are shown in Table 1. There is no

Table 1. Parameters of pulmonary function prior the HD session.

	FEV1/FVC		FEV1		FVC		FEF 25-75%	
	Obtention	Reference	Obtention	Reference	Obtention	Reference	Obtention	Reference
Men								
40-49	74.18	80.08	2.73	3.82	3.68	4.77	40-49	74.18
50-59	79.50	77.11	2.52	3.10	3.17	4.02	50-59	79.50
60-69	67.61	74.24	1.44	3.17	2.13	4.27	60-69	67.61
70-79	-	-	-	-	-	-	70-79	-
Women								
40-49	73.28	82.82	1.92	2.70	2.62	3.26	40-49	73.28
50-59	87.83	77.52	1.66	2.38	1.89	3.07	50-59	87.83
60-69	-	-	-	-	-	-	60-69	-
70-79	82.35	72.92	1.68	1.75	2.04	2.4	70-79	82.35

FEV1/FVC: Tiffeneau index; FEV1: forced expiratory volume in the first second; FVC: forced vital capacity; FEF 25-75%: forced expiratory flow between 25 and 75% of vital capacity. The values correspond to the means.

significant difference (p> 0.05) when comparing both gender and age. However, it is observed that as age increases, the values decrease, this being more noticeable in women. In addition, a trend of obtained values lower than the predicted is evidenced, especially in FEV1 and FVC, except for the value of FEV1/FVC. There was no significant difference (p> 0.05) between the mean of the initial and the final pimometry.

Table 2 shows the mean of the initial and final pimometry of the total of patients evaluated (n = 12). However, the data show a downward trend in the final pimometry.

When comparing the initial and final pimometry values according to age and gender, there was no statistically significant difference (p> 0.05) between the age ranges and gender, as shown in Table 3, but it was observed that women present lower baseline values both in the initial and final pimometry compared to men. In addition, it should be noted that as age increases, these values decrease, this being more noticeable in women.

The comparison of the initial and final pimometry in patients with and without intradialysis physical exercise did not show a statistically significant difference (p> 0.05); However, it was observed that the subjects exposed to exercise had higher values in the initial and final pimometry compared to those who have not done any exercise. Furthermore, there is a greater variation between initial and final MIP in trained versus untrained patients. All of this can be seen in Figure 1.

There are no significant differences (p> 0.05) when comparing the average of the values obtained

Table 2. Analysis of initial and final pimometry.

	n	Mean	SD	Maximum	Minimum
Initial MIP	12	71.75	39.162	24	160
Final MIP	12	68.67	33.277	16	130

MIP: maximum inspiratory pressure. SD: standard deviation. There is no statistically significant difference (p> 0.05) between the means of the initial and final pimometry.

Table 3. Analysis of initial and final pimometry according to age and gender.

Age	MIP	MIP
	Initial value	Final value
	Men	Men
40-49	>120	>120
50-59	89.25 ± 22.91	89.25 ± 4.79
60-69	70.50 ± 21.92	73.50 ± 10.61
70-79	-	-
	Women	Women
40-49	56.50 ± 0.71	60 ± 7.07
50-59	31 ± 9.90	19 ± 4.24
60-69	-	-
70-79	28	32

MIP: maximum inspiratory pressure. The values correspond to the means ± SD. There is no statistically significant difference (p>0.05) between age ranges and gender.

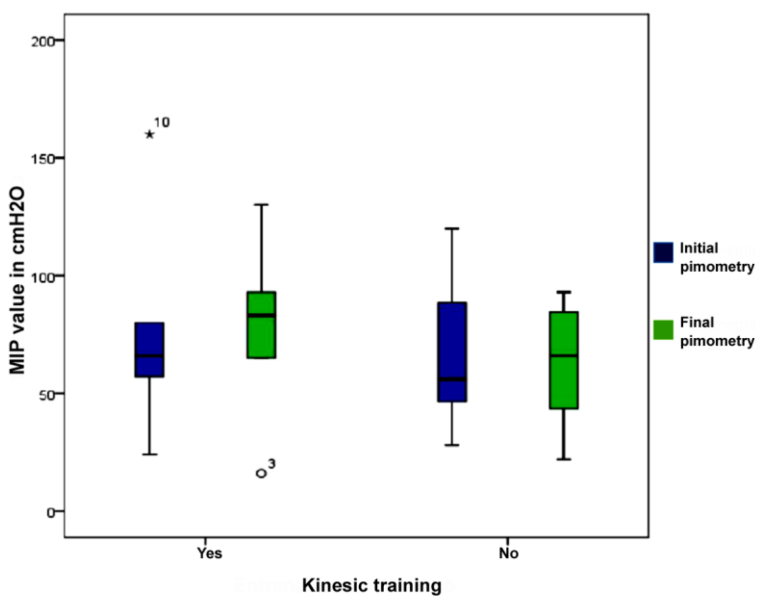

Figure 1. Comparison of initial and final pimometry in patients with and without kinesic training.

for FEV1, FVC, FEV1/FVC and FEF 25-75% between the trained and untrained subjects (Table 4). However, it was observed that the trained subjects showed better values than those untrained (with the exception of FEV1/FVC).

The subjects who performed physical exercise had values of FEV1 higher than those who had not been trained (Figure 2), as well as the values of FEF 25-75% that are shown in Figure 3.

Discussion

According to the results obtained in the study, patients undergoing hemodialysis show lower values

Table 4. Comparison of the lung function prior to HD session in trained and untrained patients.

Variable	Kinesic training	Mean	Standard deviation	Minimum	Maximum	*p* Value
FEV1	Yes	2.306	0.518	1.57	2.73	0.222
	No	1.865	0.472	1.35	2.81	
FVC	Yes	2.996	0.714	1.81	3.68	0.222
	No	2.382	0.552	1.97	3.53	
FEV1/FVC	Yes	77.7	7.814	66.45	87.05	0.755
	No	78.322	8.261	67.11	88.45	
FEF 25-75%	Yes	2.13	0.585	1.18	2.75	0.372
75%	No	1.788	0.687	0.83	2.54	

FEV1: forced expiratory volume in the first second; FVC: forced vital capacity; FEV1/FVC: Tiffeneau index; FEF 25-75%: forced expiratory flow between 25 and 75% of vital capacity. A *p*-value <0.05 is considered statistically significant.

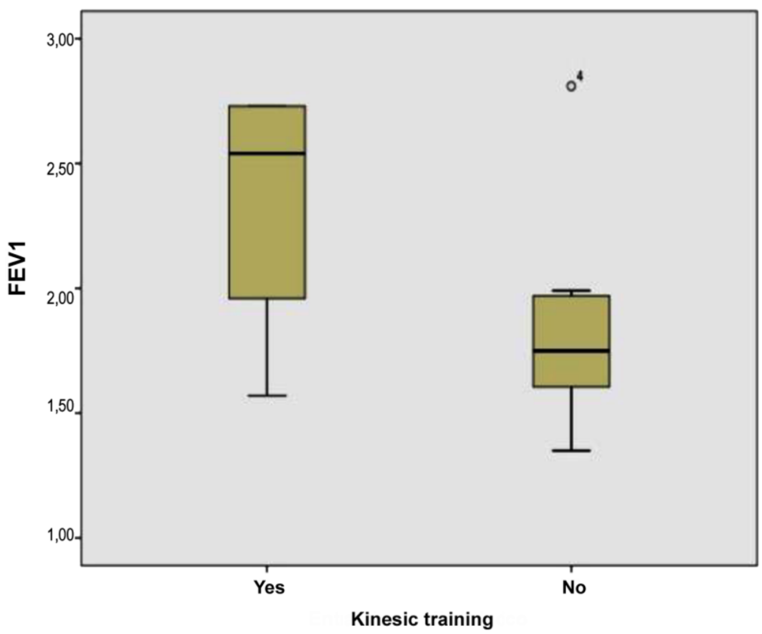

Figure 2. Comparison of mean FEV1 values between trained and untrained subjects.

in the spirometry parameters (FEV1, FVC, FEF 25-75%), except in FEV1/FVC, compared with the reference values of the Chilean population, according to Gutiérrez *et al.*[10] (Table 1). Similar results have been reported in a study carried out in 20 patients with CKD, where it is clearly reflected that the main spirometric parameters, except FEV1/FVC, are under the predictive value[13]; likewise, this is corroborated by a research carried out by Mukai *et al.*, where it was evidenced that the 404 patients with chronic kidney disease who were evaluated showed lung function outcomes under the reference values: the lower the GFR, the greater the respiratory dysfunction.[5]

In the present study, when a comparison of the spirometry parameters between both genders was made, it was observed that women had lower values

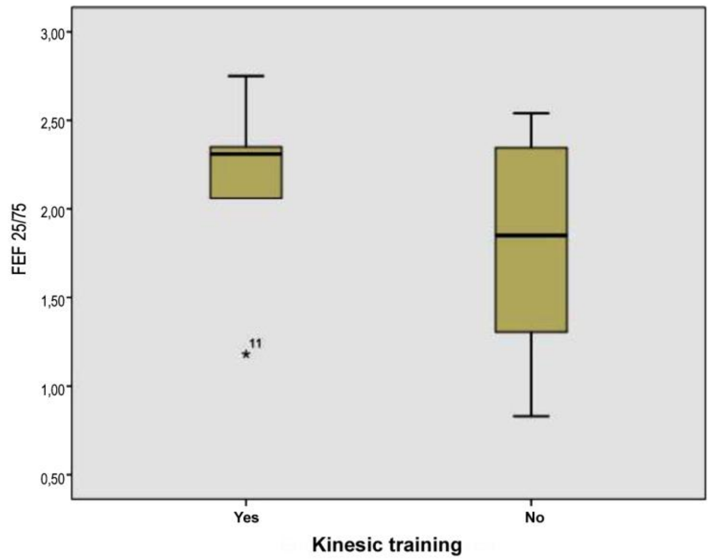

Figure 3. Comparison of mean FEF 25-75% values between trained and untrained subjects.

compared to men, which is consistent with the study conducted by Rojas and Denis, who described the baseline spirometry parameters according to sex and found that women had lower values[14]; this is explained by the study conducted by LoMauro and Aliverti, who argue that the height, more than the gender, is the main differential factor of the functional implications described.[15] On the other hand, it could be observed that at an older age, the values of the spirometry parameters decrease, which is consistent with the study conducted by Yilmaz *et al*.; this may be mainly due to the changes that occur in the respiratory system as a result of the aging process.[16] A study concluded that the level of alteration of FVC, FEV1 and FEF 25/75 in dialysis patients is due to a set of factors, including aging, inflammation, nutritional status, edema and the presence of associated comorbidities.[17] In addition, it should be noted that the decrease in the values of spirometric parameters may be mainly due to exposure to HD; this is explained by what is proposed by Palamidas *et al*., who indicate that this exposure reflects an alteration in the smaller airways and poor distribution of ventilation.[18]

On the other hand, given the FEV1/FVC values and when a comparison with the reference spirometric values at the lower limit of normality (P5) was made, the evaluated patients showed a tendency to restrictive disorders, which is corroborated by the study conducted by Sharma *et al*.[17] Some authors propose that these disorders are directly associated with circulating uremic toxins, or indirectly with fluid overload, anemia, immunosuppression, extraosseous calcification, malnutrition, electrolyte disorders and acid-base imbalances.[16]

On the other hand, when the difference between the mean of the initial and final MIPs was analyzed, a decrease in these values was observed after the HD; however, there is no significant difference between the means. These results are not consistent with those obtained by Palamidas *et al*. and Tavana *et al*., who obtained values under the predicted pre-HD and tending to increase post-HD.[18,19]

These results are similar to those published by Karacan *et al*., where lower MIP values were found after a HD session; the authors explain that this is due to the catabolic effects of HD, which also leads to carnitine depletion due to loss through the dialysis membranes, causing muscle symptoms and altered exercise capacity.[20]

In turn, when the variation of the MIP values according to the age range was analyzed, it was observed that in some groups there was an increase in the MIP at the end of the HD, which can be attributed to the fact that there were subjects who obtained values very far from the mean, which alters the average by age range. The increase in the MIP after HD coincides with the results published by Rocha and Araujo, where an increase in MIP was observed after a HD session, mainly in those patients who initially showed lower MIP values (less than 60 cm H_2O), as in the study conducted by Palamidas *et al.*, where the MIP values tend clearly upwards after the HD; the authors associate this with the unloading of the respiratory muscles and consequent improvement in the mechanics of the thorax.[18,21] On the other hand, the increase in MIP values post HD could have been influenced by the learning process of the test, since both evaluations were carried out on the same day, and it can be attributed to a better understanding of the evaluation by the patient on the second time. Another factor that could have affected the result is the interevaluator variability, since the initial and final pimometries were performed by different evaluators, which can be considered as a bias of the test.

Furthermore, it was observed in the study that the subjects who had been exposed to physical exercise had higher values in the initial and final pimometry compared to those who had not received any exercise; although it was not a significant result ($p>0.05$), there was a trend, and this is consistent with a study in which the effects of inspiratory muscle training on inspiratory muscle strength, lung function and functional capacity in CKD patients undergoing HD were evaluated and where there was also an increase in the distance covered in the 6-minute walk test; therefore, aerobic exercise can be correlated with inspiratory muscle strength.[22] It should be noted that the muscles involved in inspiration, such as the diaphragm and the intercostal muscles, are classified as skeletal muscles and there m‘ay be a decrease in muscle mass, strength and endurance due to the so-called uremic sarcopenia,[23] so it can be inferred that a lack of both muscular and aerobic training leads to a lower result in the MIP, compared to those subjects who undergo constant exercise.

At the lung function level, the parameters evaluated (FEV1, FVC, FEV1/FVC and FEF 25/75) show a clear trend, where better values are observed in those subjects who are exposed to kinesic training, with the exception of FEV1/FVC, where the untrained subjects showed on average slightly higher values, which can be attributed to a value being above the mean of the group. Even though there is no statistically significant difference, a clinically significant difference can be established.

The group of patients exposed to intradialysis physical exercise showed higher FEV1 values, which is consistent with what was proposed by Fatima *et al.*, where a group of healthy patients subjected to aerobic training showed better values compared with the group without training; and the FVC and FEV1/FVC values also improved.[24]

On the other hand, in the study published by Silva *et al.*, an increase in FEV1 values was also observed after a training program for subjects with CKD; however, this training focused specifically on the inspiratory muscles, which suggests to carry out a work focused on improving the performance of the ventilatory muscles.[22] Aerobic training has a positive effect on inspiratory muscles, but aerobic training combined with inspiratory training is suggested in order to achieve better results.[25]

Among the limitations of the study is the low number of patients, which was mainly due to the inclusion and exclusion criteria; on the other hand, many patients refused to participate and others dropped out during the evaluations. One of the biases that cannot be ruled out is the existence of a learning process for the evaluations, which might have influenced the results.

It should be highlighted that although there was no statistically significant difference, a clinically significant difference could be confirmed.

Conclusions

Patients undergoing the hemodialysis process have a lung function and ventilatory capacity under predictive values. Those patients who have exercised or who are in an intradialysis exercise program, either aerobic, strengthening or combined, present better spirometric and pimometric values than those who have not carried out any type of exercise.

It is necessary to carry out intradialysis training programs that not only include aerobic work and limb muscle strengthening exercises, but that also include ventilatory work, to know if the inclusion of the latter improves even more the respiratory and cardio-respiratory parameters of these patients.

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Conflict of interest and funding

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Ethical responsibilities

Protection of people and animals

The authors declare that no experiments were performed on human beings or animals for this research.

Data confidentiality

The authors declare that they have followed the protocols of their workplace on the publication of patient data.

Right of privacy and informed consent

The authors declare that patient data do not appear in this article

Contribution of the authors

This research is original and unpublished. All authors have contributed significantly to the present study from the conception to the submission of the manuscript.

Paula Moscoso was the manager of the research idea, constant guide of the study, literature reviewer and organizer of the manuscript to be submitted to this scientific journal; Yessica Aliante, Nayareth Becerra and Keren Quezada were the evaluators of the hemodialysis patients, literature reviewers, and writers of the initial article. Luis Ojeda was the constant statistical advisor of the study.

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