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Consequences of chronic renal insufficiency on the exercise capacity, nutritional status, pulmonary function and respiratory musculature of children and adolescents

Repercussões da insuficiência renal crônica na capacidade de exercício, estado nutricional, função pulmonar e musculatura respiratória de crianças e adolescentes

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Abstract

Objective: To evaluate functional capacity, pulmonary function, respiratory musculature and nutritional status among children and adolescents with chronic renal insufficiency (CRI) undergoing conservative treatment. **Methods:** This study was conducted with 30 volunteers, divided into two groups: a group of children and adolescents with CRI undergoing conservative therapy (CRI Group) and a group without renal disease (Control Group). The volunteers underwent physical therapy evaluation, spirometry, strength and resistance tests on their respiratory musculature, nutritional status evaluation and functional capacity assessment. The data were analyzed using the Mann-Whitney test with a significance level of 5%. **Results:** The Tiffeneau index was significantly lower in the CRI Group ($p= 0.003$). In relation to respiratory muscle function, the maximum expiratory pressure values were lower ($p= 0.010$) and the time values of the resistance test were greater ($p= 0.003$). In the functional assessment, the variables that differed statistically were: lower distance walked ($p< 0.001$), greater mean arterial pressure ($p< 0.001$), final respiratory rate ($p< 0.001$) and Borg scale ($p= 0.048$). Regarding nutritional status, all the statistically significant variables were lower. **Conclusions:** Children and adolescents with CRI undergoing conservative treatment may present significantly impaired functional capacity, respiratory musculature and nutritional status.

Key words: chronic renal insufficiency; children; adolescent.

Resumo

Objetivo: Avaliar a capacidade funcional, função pulmonar, musculatura respiratória e estado nutricional de crianças e adolescentes portadores de insuficiência renal crônica (IRC) em tratamento conservador. **Métodos:** Este estudo foi realizado com 30 voluntários, divididos em dois grupos: Portadores de IRC em tratamento conservador (Grupo IRC) e grupo sem comprometimento da função renal (Grupo Controle). Os voluntários foram submetidos à avaliação fisioterapêutica, espirometria, avaliação de força e resistência da musculatura respiratória, do estado nutricional e da capacidade funcional. Para a análise dos dados, foi utilizado o teste de Mann-Whitney com nível de significância de 5%. **Resultados:** No Grupo IRC, o índice de Tiffeneau foi significativamente menor ($p= 0,003$). Em relação à função muscular respiratória, os valores de pressão expiratória máxima foram menores ($p= 0,010$) e os valores do tempo do teste de resistência, maiores ($p= 0,003$). Na avaliação funcional, as variáveis que diferiram estatisticamente foram: menor distância caminhada ($p< 0,001$) e maior pressão arterial média ($p< 0,001$); freqüência respiratória final ($p< 0,001$) e escala de Borg ($p= 0,048$). Quanto ao estado nutricional, todas as variáveis, estatisticamente significativas, foram menores. **Conclusões:** Crianças e adolescentes portadores IRC, em tratamento conservador, podem apresentar alterações importantes da capacidade funcional, musculatura respiratória e estado nutricional.

Palavras-chave: insuficiência renal crônica; criança; adolescente.

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Introduction

Chronic renal insufficiency (CRI) is characterized by progressive and irreversible destruction of renal structures[1]. The respiratory system suffers alterations in respiratory drive, pulmonary mechanics, muscle function and gas exchange[2-4]. This pulmonary dysfunction may be a direct result of the circulation of toxins or, indirectly, from the excess volume due to the increased quantities of circulating body fluids, anemia, immunological suppression, drugs and deficient nutrition[5-7].

Physiological abnormalities are frequent in the skeletal muscle structure of patients with CRI, and their main signs are fatigue, muscular weakness and low exercise tolerance[4-8]. Regarding respiratory muscular weakness, maximum respiratory pressure measurements may help in the diagnosis and therapeutic interventions for these patients[8]. For physical activity, the evaluation can be done through specific effort tests[9,10]. The six-minute walking test (6WT) is one of these tests, and this tool very reliably reflects the practice of functional activities of daily living[11].

Both muscle weakness and CRI treatment cause alterations to respiratory functions. Conservative treatment, or reposition therapy, consists of a method for preventing or retarding deterioration of the remaining renal functions. It helps the organism to compensate for the existing disorder before opting for dialysis therapy or kidney transplantation[12].

Because there is no consensus in the literature regarding the degree of functional and respiratory muscular impairment in children with CRI, the objective of this study was to evaluate the impairment of pulmonary functions, functional capacity and nutritional states among children and adolescents with CRI undergoing conservative treatments, and to compare them with children and adolescents without impaired renal functions.

Materials and Methods

Volunteers

This study began after gaining approval from the Research Ethics Committee of the Universidade Federal de Minas Gerais in accordance with report numbers ETIC 571/ 04 and ETIC 572/04, and after obtaining free and informed consent in writing from the adults legally responsible for the volunteers. Thirty volunteers were included and divided into two groups: children and adolescents without renal function impairments (control group); and children and adolescents with CRI undergoing conservative treatments (CRI group), i.e., individuals with prescriptions for diet modifications, diuretic medications and anti-hypertensive medication, along with electrolytic repositioning.

Volunteers aged between six and 16 years old were evaluated and regrouped according to their age and sex. To avoid interference due to age differences, the results were matched according to age and sex. The volunteers with CRI were selecting from clinical and laboratorial diagnoses. Volunteers who were excluded from this study were those demonstrating hemodynamic instability, recent or chronic pulmonary or cardiac diseases, drug use affecting respiratory muscle function and/or strength, severe uremia symptoms, neuromuscular dysfunctions, osteoarticular dysfunctions or difficulty in understanding and accomplishing the proposed tests, or who refused to participate in this study[1-3]. For the control group, volunteers without impaired renal function, as confirmed by urinalysis, were selected. The exclusion criteria were the same as for the CRI group.

Evaluation methods

The volunteers underwent a standard physical therapy evaluation. Following this, tests were carried out to evaluate pulmonary functions (spirometry), respiratory muscular strength and resistance, nutritional states and functional capacity. Each evaluation was done by four independent examiners who were blind in relation to the volunteer group.

The spirometry was performed with the use of a computerized spirometer, in accordance with the policy proposed by ATS/ERS[13]. The following were evaluated: forced vital capacity (FVC), forced expiratory volume in the first second (FEV_1) and the Tiffeneau ratio (FEV_1/ FVC). The values were expressed as absolute values and percentages of expected values[14].

The functional capacity was evaluated using the 6WT in accordance with the policy proposed by ATS[11]. The respiratory rate (RR), arterial pressure (AP), heart rate (HR) and pulse oximetry (SpO_2) were measured at the beginning and at the end of each test. The effort dyspnea rate was evaluated using the Borg scale. The objective of evaluating these variables was to investigate possible alterations in the cardiopulmonary system caused by the test. During the entire walk there was constant monitoring of the HR by using an HR monitor and of the SpO_2 by using an oximetry apparatus (Nonin Onyx® model 9500). The volunteers did at least two 6WTs and the differences in the distance walked between the tests was required to be no more than 10%.

The maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP) were evaluated as respiratory muscular strength indicators, in accordance with the method proposed by Black and Hyatt[15]. The pressures were measured using an analog manovacuometer (Gerar®; 0 ± 300 cmH_2O). In the final analysis, the greatest measured value was considered, such that the differences between the two greatest values needed to be no more than 5%. The values were expressed in percentages of expected values[16].

To evaluate inspiratory muscular resistance, the protocol of Jong et al.[17] was used. The test was initiated with a pressure of 30% of MIP and, every two minutes, the load on the muscle trainer was increased by 10% of MIP. The maximum load was the greatest load that the patient managed to sustain for over a minute. HR, RR and SpO_2 were evaluated before and after each test. The Borg scale was also used, to verify whether the increased load during this test could be responsible for cardiopulmonary alterations and also whether the volunteer could be using any respiratory strategies for maintaining higher loads.

To evaluate the volunteers' nutritional state, their age, weight and height were verified. For children of zero to nine years old, the anthropometric weight/age (W/A) and height/age (H/A) indices were used. The anthropometric reference used was from the National Center for Health Statistics (NCHS), as recommended by the World Health Organization and has been used by the Brazilian Health Ministry since 1976. The children with weight/age or weight/height below −2 standard deviations of the curves, were classified as undernourished (low weight) and those with height/age below −2 standard deviations as demonstrating height deficit. Children who were below −1 standard deviation (Z score) from the reference mean were considered to present nutritional risks. Children with weight/age above +2 standard deviations were classified as indicating excessive weight. To analyze the children and adolescents from 10 to 16 years old, the body mass index (BMI) was used in relation to age (BMI/A). Children with BMI/A below the fifth percentile were deemed to have low weight levels and above the 85^{th} percentile, excessive weight[18]. Arm circumference measurements were carried out on the non-dominant upper limb, with the arm hanging and relaxed beside the body, at the midpoint between the acromion and the olecranon. Three measurements were made and the value that was considered valid was the mean of the closest two values[19].

Statistical Analyses

The *Kolmogorov-Smirnov* test was used to analyze whether the distribution was normal and the data were analyzed using the Mann-Whitney test. The results were considered significant at a significance level of 5% with a confidence interval of 95%.

Results

During this study, thirty-six volunteers were evaluated. Of these, six were excluded due to mental problems (n= 2) and skeletal muscle disorders (n= 4). Of the remaining thirty volunteers, 15 were in the CRI group and 15 in the control group (seven men and eight women in each group). The mean age of the volunteers was 11.13 ± 3.35. The body weight and height values in the CRI and control groups were 30.93 ± 9.75 kg and 38.20 ± 12.19 kg and 136.33 ± 14.26 cm and 146 ± 15.09 cm, respectively. In the spirometry, the CRI group demonstrated significantly lower values for the Tiffeneau ratio (FEV_1/ FVC) (Table 1).

In the respiratory muscular strength evaluation, the CRI group demonstrated significantly lower MEP values. For the inspiratory muscular resistance before, during and after the test, the HR, RR, Borg scale and SpO_2 were evaluated. The CRI group demonstrated significantly longer test durations, but the final RR, final HR and Borg scale were significantly higher. However, the maximum loads reached by the two groups were not different (Table 2). In relation to the 6WT, the mean arterial pressure (MAP), final *f* and Borg scale were significantly higher in the CRI group. However, the volunteers in the CRI group walked less distance (Table 3).

In the nutritional evaluation, 53.33% of the CRI group volunteers were eutrophic, 26.6% were at nutritional risk; and 20% demonstrated low weight and low height. Among the control group, 73.3% of the volunteers were classified as eutrophic, 13.3% at nutritional risk, 6.66% with low weight and 6.6% with excessive weight.

With regard to their nutritional composition, 73.4% of the CRI group demonstrated muscular depletion and 26.6% had normal muscle reserves. There was adipose tissue depletion in 47% of the group, while 53% had normal reserves. In the

Table 1. Descriptive and comparative analyses of spirometry measurements between the groups.

Variable	CRI group (n=15)	Control group (n=15)	PE (CI)	p
FVC (liters)	2.14	2.26	-0.29 (-0.77; 0.29)	0.309
FVC (% of expected)	94.00	99.00	-2.00 (-14.00; 8.99)	0.693
FEV_1 (liters)	1.70	2.02	-0.30 (- 0.72; 0.14)	0.140
FEV_1 (% of expected)	86.00	96.00	-10.00 (-21.00; 0.99)	0.101
FEV_1/FVC (% of expected)	91.00	98.00	-6.00 (-10.00; 2.00)	0.003

FVC: forced vital capacity; FEV_1: forced expiratory volume in first second; FEV_1/FVC: Tiffeneau ratio. The values of FVC, FEV_1 and FEV_1/FVC are expressed as medians. PE and CI are point estimates and confidence intervals.

Table 2. Descriptive and comparative analyses between the groups regarding inspiratory (MIP) and expiratory (MEP) muscle strength and inspiratory muscle resistance measurements.

Variable	CRI group (n=15)	Control group (n=15)	PE (CI)	p
MIP (% of expected)	163.26	154.64	15.58 (-18.62; 47.17)	0.340
MEP (% of expected)	75.11	130.20	-44.08 (-71.78; -13.02)	0.010
Test duration (seconds)	218.00	101.00	87.00 (36.10; 202.00)	0.003
Maximum load (cmH_2O)	39.00	36.00	-1.00 (-19.99; 10.00)	0.884
Initial RR (rpm)	14.00	13.00	-1.00 (-2.99; 1.00)	0.272
Initial HR (bpm)	92.00	93.00	-2.00 (-10.00; 5.00)	0.466
Initial SpO_2 (%)	98.20	97.53	-1.00 (-2.00; 0.00)	0.011
Final RR (rpm)	26.00	17.00	10.00 (5.99; 12.00)	< 0.001
Final HR (bpm)	100.00	82.00	18.00 (8.00; 26.00)	0.006
Final SpO_2 (%)	98.00	98.00	-0.00 (-1.00; 1.00)	0.945
Borg	17.00	13.00	2.00 (1.00; 5.00)	0.008

MIP: maximum inspiratory pressure; MEP: maximum expiratory pressure; RR: respiratory rate; HR: heart rate; SpO_2: pulse oximetry. The values of the variables are expressed as medians. PE and CI are point estimates and confidence intervals.

control group, 53.4% of the volunteers had muscular depletions, while 26.6% demonstrated normal muscle mass. In their adipose tissue, 40% had depletion, while 60% showed normal reserves.

In comparing the groups regarding arm muscle circumference (AMC) variables and Z scores for height/age and weight/age, there were significant differences. In relation to the body mass index (BMI) percentages, there were no significant differences (Table 4).

Discussion

The results demonstrated that there was a statistically significant decrease in the Tiffeneau ratio in the pulmonary function test among the CRI group volunteers, although the values remained within clinically normal parameters. Siafakas et al.[2] showed that patients with CRI may demonstrate limitations in their airflow. According to these authors, the reduction in FEV_1 may be associated with diminished muscular strength, which is responsible for the delays in muscle fiber contraction[2]. Dujic et al.[20] also described decreases in all spirometric variables, including FVC, and attributed these decreases to reversible obstructions in the airways and to trapped air caused by accumulations of liquid near the airways[20]. However, one study stated that patients with CRI undergoing conservative treatments might have spirometry values within the normal range because of greater preservation of pulmonary functions[12], just as observed in the present study.

It is very clear from the literature that weaknesses of the respiratory muscles are one of the complications of CRI[21-24]. However, the cause of this weakness is uncertain. It has been suggested that it is related to carnitine and vitamin D deficiencies and excesses of the parathyroid hormone[25,26]. There have also been reports that it is caused by hypotrophy of type II muscle fibers and alterations of myofibrillar ATPase, thus causing an energy use deficit[2].

In the present study, it was observed that the patients with CRI demonstrated weakness only in the expiratory muscles. Since these patients were undergoing conservative treatments, which is less invasive, and had a mean age of 11.13 ± 3.35 years (i.e., they were young patients), it was possible for their inspiratory muscular strength was still preserved. Another hypothesis for the expiratory muscular weaknesses could relate to sedentarism among the individuals with CRI and to respiratory mechanics, since inspiration is an active process while expiration is passive, the expiratory muscles of these patients might have become weaker through disuse[27].

In the muscular resistance test, the individuals in the CRI group managed to achieve significantly longer test durations, although there were no differences in the maximum loads attained between the groups. The CRI group demonstrated a significantly increased final f, thus suggesting that the volunteers in the CRI group may have used respiratory strategies such as increased f, to be able to tolerate the imposed loads for a longer period. Clanton et al. stated that respiratory muscular resistance measurements are a function of respiratory patterns and that alterations in these patterns might interfere in the length of time for which respiratory loads can be sustained[26]. However, other authors have stated that the significant differences between the f values in respiratory muscular tests are not important variables in relation to load tolerance[28,29]. Thus, there is controversy in the literature regarding these results, and the findings from the present study cannot confirm that the patients in the CRI group had inspiratory muscular resistance that was better than that of the control group volunteers.

Table 3. Descriptive and comparative analyses between the two groups in relation to functional capacity, evaluated by means of the six-minute walking test.

Variable	CRI group (n=15)	Control group (n=15)	PE (CI)	p
Distance (meters)	560.00	724.00	-158 (-226.00; -88.00)	< 0.001
MAP (mmHg)	96.66	83.33	13.33 (6.67; 18.33)	< 0.001
Initial RR (rpm)	14.00	13.00	-1.00 (-2.99; 1.00)	0.272
Final RR (rpm)	30.00	15.00	15.00 (11.00; 17.00)	< 0.001
Initial HR (bpm)	92.00	93.00	-2.00 (-10.00; 5.00)	0.466
Final HR (bpm)	145.00	150.00	-12.00 (-29.01; 4.00)	0.164
Initial SpO_2 (%)	98.00	98.00	-0.00 (-1.00; 1.00)	0.945
Final SpO_2 (%)	97.00	96.00	-0.00 (-1.00; 2.00)	0.732
Borg	15.00	11.00	2.00 (-0.001; 4.001)	0.048

MAP: mean arterial pressure; RR: respiratory rate; HR: heart rate; SpO_2: pulse oximetry. The values of the variables are expressed as medians. PE and CI are point estimates and confidence intervals.

Table 4. Descriptive and comparative analyses between the groups in relation to nutritional variables.

Variable	CRI group (n=15)	Control group (n=15)	PE (CI)	p
AMC (cm)	17.16	19.44	-2.37 (-4.54; -0.43)	0.018
Z= height/age	-0.70	0.23	-1.30 (-2.19; -0.37)	0.007
Z= weight/age	-0.86	-0.43	-0.90 (-1.89; -0.12)	0.029
BMI percentile	24.31	20.60	0.50 (-223.33; 23.68)	0.950

ACM: arm muscle circumference; BMI: body mass index. The values of the variables are expressed as medians. PE and CI are point estimates and confidence intervals.

In relation to the 6WT, it was observed that the CRI group demonstrated significantly shorter walking distances, and this was associated with increased MAP, final *f*, final SpO_2 and Borg scale values. This confirmed the worsening of these values in regard to practicing functional activities of daily living, among patients with CRI, even when younger and undergoing conservative treatments. Moreover, cardiac performance is frequently abnormal in individuals with CRI and may also be present in patients of a younger age, thus causing impairments of physical activity practices and quality of life[29].

In the nutritional analysis, it was observed that 20% of the individuals in the CRI group were below normal weight and a lower height. In the control group, only 6.66% of the volunteers were underweight, and none of them were very short. It was also observed that the CRI group demonstrated significantly decreased AMC and Z-scores for height/age and weight/age. Children with renal disorders commonly show abnormalities of growth and body weight and malnutrition is a determining factor for reduced growth among such children[29,30]. In the CRI group, 73.4% of the volunteers demonstrated muscular depletions, compared with 53.4% in the control group. Bark et al.[23] suggested that the nutritional state and body weight might generate weaknesses of the respiratory muscles, which may be another of the causes of the expiratory muscular weaknesses that were found among the volunteers in the present study [24].

Conclusions

The data found in the present study indicated that patients with CRI may show decreased functional performance and impairment of physical activity practices. Therefore, these findings contribute towards better therapeutic options, through optimizing the clinical treatment and helping professionals in their interventions.

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