Comparison of Baroreflex Response to Acute Sessions of Strength and Aerobic Exercises in Kidney Recipients

Carlos J. Dias, Luana Monteiro Anaisse-Azoubel, Erika Cristina Ribeiro de Lima Carneiro, Bruno Rodrigues, Antonio Carlos Silva-Filho, Maria Claudia Irigoyen, Carlos Alberto Alves Dias-Filho, Francisco Navarro, Márcio Sevilio Jr, Cristiano T. Mostarda

1Universidade Federal do Maranhão - UFMA, São Luís, Brasil, 2Laboratório de Adaptações Cardiovasculares ao Exercício – LACORE, UFMA, São Luís, Brasil, 3Faculdade de Educação Física, Universidade de Campinas – UNICAMP, Campinas, Brasil, 4Departamento de Cardiopneumologia da Faculdade de Medicina da USP, Chefe do Laboratório de Hipertensão Experimental do InCor - HC-FMUSP, São Paulo, Brasil, 5Centro de Prevenção de Doenças Renais – CPDR, HUUFMA, São Luís, Brasil

ABSTRACT

Dias CJ, Anaisse-Azoubel LM, Carneiro ECRL, Rodrigues B, Silva-Filho AC, Irigoyen MC, Dias-Filho, Carlos AA, Navarro F, Sevilio Jr M, Mostarda CT. Comparison of Baroreflex Response to Acute Sessions of Strength and Aerobic Exercises in Kidney Recipients. JEPonline 2017;20(5):123-133. This study compared the autonomic modulation and baroreflex sensitivity responses to acute session of aerobic and strength exercises in kidney recipients. Ten (6 men and 4 women) kidney-recipient patients joined the study. All patients were enrolled in a regular exercise program. The same group undertook two different exercise protocols in separate days (strength and aerobic), with baroreflex and autonomic activity evaluations before and 60 min after each session. Both groups showed similar behaviors at rest, but differences were found only after aerobic exercise regarding baroreflex sensitivity. The behavior of the autonomic system was reestablished after aerobic exercise. However, the same finding did not occur with strength exercise. This information is important because autonomic recovery after exercise is an important index for long-term training periodization.

Key Words: Baroreflex, Exercise, Kidney Transplantation
INTRODUCTION

Kidney transplantation (KT) is the final treatment alternative for chronic kidney disease. It is a means to restoring endocrine and filtration functions successfully (5). In Brazil, exactly 18,818 patients are waiting for kidney transplantation. This represents 17% of the patients actually in the dialysis process. In the first trimester of 2016, 1,305 kidney transplantations surgeries occurred in Brazil, while in the state of Maranhão only six kidney transplantations took place, positioning the state in 17th place among all Brazilian states (31,32). Aside from the chronic kidney disease (CKD) complications, cardiovascular events still lead death among CKD patients (4,18,23). Recent studies have demonstrated altered autonomic activity in CKD patients (26), which can be one of the possible reasons for a high risk of cardiovascular disease. Regarding this issue, one of the main hemodynamic control mechanisms is the baroreflex (10) that regulates heart autonomic balance and other physiological indexes like blood pressure (39) and renal blood flow (40).

Exercise has been identified as an important non-pharmacological tool in the treatment of autonomic imbalance in heart and kidney diseases, as shown by numerous studies (16,27,29). Deligiannis et al. (15) indicate that exercise triggers positive baroreflex responses in dialytic patients as measured by heart rate variability (HRV). However, no data exist regarding autonomic behavior in recovery after different exercise types in kidney recipients. The recovery is a primal part of exercise prescription, being affected by compensatory mechanisms such as chemoreceptors, metaboreceptors and, mechanoreceptors (17,33).

Exercise-related benefits (e.g., decreased blood pressure and heart rate) are driven mainly by the autonomic nervous system and baroreflex adaptations as a the result of the increase in vagal tone and the decrease in sympathetic tone, which are mostly achieved through aerobic exercises (15,36). Although studies using strength exercises also encountered changes in baroreflex responses and, consequently, in its dependent mechanisms, such as blood pressure both in hypertensive and normotensive individuals (28,37), as well as reductions is systolic and diastolic blood pressure in patients with intermittent claudication (13), thus indicating that strength exercises can also cause positive baroreflex adaptations.

Both strength and aerobic exercises can positively affect baroreflex and autonomic nervous system activities. With regard to these benefits, the purpose of this study was to evaluate the autonomic modulation and baroreflex sensitivity responses to acute session of aerobic and strength exercises in kidney recipients. We hypothesized that baroreflex sensitivity is more likely recovered after the aerobic exercise and not after strength exercises.

METHODS

Subjects

Ten (6 men and 4 women) kidney-recipient patients joined the study from the Centro de Prevenção de Doenças Renais do Hospital Universitário do Maranhão, São Luís, Brazil. All patients were in a regular exercise program and described as actives, as shown by the IPAQ questionnaire (3). To join the study, patients had to meet the following criteria: (a) at least 6 months from the KT surgery; (b) older than 18 yrs of age; (c) ability to perform an exercise session; and (d) stable blood pressure and glycemia according to their medical records. Patients with other heart or circulatory diseases (atrial fibrillation, congestive heart failure, pacemakers, arrhythmias, etc.) could not join the study due to high risk of cardiac events and
possible bias in heart rate variability and baroreflex analysis. All inclusion criteria followed guidelines for hypertension (19), diabetes (7), and smoke control (14).

**Procedures**

**Anthropometric Analysis**
The subjects' weight and height were measured using a digital scale with a stadiometer (Balmak, São Paulo, Brazil). Subjects were instructed to remain in an orthostatic position. A tetrapolar bioimpedance was used for the percentage of fat and muscle mass (BF 906, Maltron, Rayleigh, UK). They were instructed to: (a) abstain from eating and drinking within 4 hr of the test; (b) abstain from physical exercise on the test day; (c) urinate 30 min before the test; and (d) avoid consuming alcohol within 48 hr of the test.

**Blood Analysis**
The biochemical markers were collected at the University Hospital Laboratory, where the procedure was performed by a technician or nurse on duty and stored in a 10 mL test tube that was taken to automate analysis in the ADVIA 2120i Hematology System (Siemens Healthcare Diagnostics, Forchheim, Germany). Serum concentrations of uric acid (mg·dL\(^{-1}\)), phosphorus (mg·dL\(^{-1}\)), creatinine (mg·dL\(^{-1}\)), fasting blood glucose (mg·dL\(^{-1}\)), HDL cholesterol (mg·dL\(^{-1}\)), and triglycerides (mg·dL\(^{-1}\)) were analyzed.

**Autonomic Modulation and Baroreflex Measurements**
The BP waveforms were obtained by a digital photoplethysmography device (Finapress Medical System) while the subjects were awake in a supine position. The data were collected between 8 and 10 AM during a 10-min period. A software program (BeatScope) used the blood pressure (BP) curves and the patients' age, sex, weight, and height values to calculate systolic and diastolic BP, heart rate (HR), cardiac output, and peripheral vascular resistance. The waveforms were simultaneously recorded on another computer equipped with acquisition and conversion of biological signals AT/MCA-CODAS (DATAQ Instruments, Akron, OH). The sampling frequency of signals was set at 1,000 Hz. These stored data underwent a routine analysis to provide the values of HR and BP variability. Each heartbeat was identified by the use of a specialized algorithm implemented for the Matlab MT (MATLAB 6.0, Mathworks), which makes the automatic detection of events of systolic and diastolic pressure waves. Pulse interval or R-R interval was calculated as the difference between the beginning and end points of the cycle (t\(_1\)-t\(_0\)). The power spectral density of R-R interval was obtained by the fast Fourier transformation using the Welch's method over 16,384 points with a Hanning window and 50% overlapping. The spectral bands for humans [very low-frequency (LF): 0.0 – 0.04 Hz; LF: 0.04 – 0.15 Hz; and high frequency (HF): 0.15 – 0.4 Hz] were defined according to literature references.

**Exercise Protocols**
Aerobic exercise was performed in a horizontal cycle ergometer (Athletic, active 50 BH) for 30 min, where exercise intensity was controlled by the subject's rate of perceived exertion, through Borg scale (moderate levels in 12 to 13, slightly tiring). Strength exercise included local muscular endurance (LME) exercises, with 3 sets of 15 reps with isotonic contractions with 2-sec duration for each type of contraction (concentric and eccentric) using the alternating segment method. The sequence of movements was: 1, unilateral knee flexion in standing position; 2, shoulder abduction in standing position; 3, leg abduction in the lateral
position; 4, scapular retraction in sitting position; 5, elbow flexion in standing position; 6, unilateral knee extension in sitting position; 7, leg adduction in the lateral position; and 8, elbow extension in the supine position.

The Borg scale was used to determine exercise intensity with the range proposed of 12 to 13 (slightly tiring). The anklets and dumbbells calibrated in 0.5 kg were used to add resistance to the movement with intervals of 60 sec between sets. Blood pressure was constantly monitored every 5 min for safety reasons. The total strength session duration was around 30 min after subtracting the rest intervals. After 60 min of rest, the subject was connected to the Finapress machine (Finapress Medical Systems, Amsterdam, Netherlands) for 10 min of signal inflow. The exercise order was randomly selected (aerobic or strength), with a 1-wk rest interval between the experimental sessions.

**Statistical Analysis**

The data were analyzed in Prism 5 (GraphPad, La Jolla, CA, USA) software. The Shapiro-Wilk test was used to assess data normality, presented as mean and standard deviation. For statistical differences in characteristics between the exercise regimens, the one-way ANOVA was used for normally distributed variables. A significance level of P<0.05 was adopted.

**RESULTS**

**Table 1. Subjects’ Baseline Indexes in the Kidney Recipients.**

<table>
<thead>
<tr>
<th></th>
<th>KT (n = 10)</th>
<th>Reference Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong> (yrs)</td>
<td>43.10 ± 13.02</td>
<td>----</td>
</tr>
<tr>
<td><strong>Weight</strong> (kg)</td>
<td>70.82 ± 13.21</td>
<td>----</td>
</tr>
<tr>
<td><strong>Height</strong> (cm)</td>
<td>161.82 ± 10.25</td>
<td>----</td>
</tr>
<tr>
<td><strong>Fat Mass (%)</strong></td>
<td>24.09 ± 8.13</td>
<td>----</td>
</tr>
<tr>
<td><strong>Lean Mass (%)</strong></td>
<td>51.52 ± 12.59</td>
<td>----</td>
</tr>
<tr>
<td><strong>CKD Time</strong> (months)</td>
<td>144.22 ± 88.59</td>
<td>----</td>
</tr>
<tr>
<td><strong>Dialysis Time</strong> (months)</td>
<td>33 ± 33.12</td>
<td>----</td>
</tr>
<tr>
<td><strong>Transplant Time</strong> (months)</td>
<td>49.40 ± 33.56</td>
<td>----</td>
</tr>
<tr>
<td><strong>Systolic Blood Pressure</strong></td>
<td>114.18 ± 13.99</td>
<td>----</td>
</tr>
<tr>
<td><strong>Diastolic Blood Pressure</strong></td>
<td>67.27 ± 6.70</td>
<td>----</td>
</tr>
<tr>
<td><strong>Hemoglobin</strong> (mg·dL⁻¹)</td>
<td>14.15 ± 1.33</td>
<td>11.3 - 16.3 Females</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12.8 - 17.8 Males</td>
</tr>
<tr>
<td><strong>Hematocrit (%)</strong></td>
<td>42.45 ± 4.23</td>
<td>36 - 48 Females</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40 - 54 Males</td>
</tr>
<tr>
<td><strong>Creatinine</strong> (mg·dL⁻¹)</td>
<td>1.28 ± 0.32</td>
<td>.40 - 1.40</td>
</tr>
<tr>
<td><strong>Glycemia</strong> (mg·dL⁻¹)</td>
<td>107.36 ± 17</td>
<td>60 – 99</td>
</tr>
<tr>
<td><strong>Uric acid</strong> (mg·dL⁻¹)</td>
<td>6.54 ± 0.95</td>
<td>1.5 - 6.0 Females</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.5 - 7.0 Males</td>
</tr>
</tbody>
</table>

Table 1 indicates that the subjects’ values at rest are within the normal range. Regarding heart rate variability (HRV), no differences were found in the subjects’ autonomic activity between exercise regimens, neither in time (RR, SDRR) nor in frequency domain (LF ms⁻², HF ms⁻², LF (%), HF (%), and LF/HF), indicating no alteration in autonomic modulation (Table 2).
In Table 2, low-frequency band (mmHg$^2$) of systolic arterial pressure variability (SAPV) (All gain [ms/mmHg], up gain [ms/mmHg] and, down gain [ms/mmHg]) revealed significant differences between resting and after strength exercise that indicates increased sympathetic activity. However, similar results were not observed in the after aerobic exercise session with no significant differences between the exercise regimens. The alpha index was similar in strength and aerobic exercise. However, the up and down gains were lower after the strength exercise and similar in the aerobic exercise.
DISCUSSION

In the present study, we compared the acute effect of aerobic and strength exercises at autonomic modulation and spontaneous baroreflex in kidney-transplanted recipients. The main finding of this work was that the strength exercise did not elicit baroreflex recovery, as did aerobic exercise in the kidney recipients.

This finding is important in regards to autonomic recovery after exercise, given that it is an important index for long-term training periodization. This could be crucial for patients once they have a low threshold for peripheral fatigue. The proper recovery time promotes specific gains in accordance with the training purpose. However, it is also important to point out that improper recovery time can cause muscle injuries (9,11,21,30).

The LF of the SAPV oscillations are linked with the sympathetic vascular response to the baroreflex stimulation and inhibition (12). Similarly, in a study by Somers et al. (38) that analyzed BRS in hypertensive patients, before, and 10, 20, 40, and 60 min after maximum intensity exercise, the results showed that BRS was decreased 10 min after the exercise, recovered at 20 min, and increased at 40 and 60 min, which is consistent with the same pattern that was found in the present study (38).

Although the strength exercise intensity was measured subjectively through Borg scale and adjusted according to the perception of each subject, it may have been underestimated in the present study. The cause of the decrease in SBR has been attributed to multiple factors such as autonomic neuropathy, chronic hypertension, heart failure, anemia, and changes in arterial distensibility. The most likely explanation for the decrease in SBR seems to be a defect in the parasympathetic efferent pathways of the baroreflex arch. The autonomic adjustment that controls the blood pressure response during exercise is activated by the sympathetic nervous system (SNS). The SNS redirects blood flow to the skeletal muscles in activity, preventing excessive vasodilation caused by increases in metabolites inside the active muscle (34). In resistance exercise, along the isometric contraction, the increase in HR becomes more evident due to the contribution of the sympathetic nervous system (22). In aerobic exercise, there is a widespread vasodilation and decreased peripheral vascular resistance, which explains the maintenance of diastolic blood pressure (8).

In the present study, the sympathetic periphery remained elevated without exercise, thus demonstrating no LF index of blood pressure. It is likely a function of the energy deficit that is greater than strength exercise and, consequently, the greater sympathetic activation and the lower baroreflex sensitivity due to the increase of the metaboreflex and chemoreflex activities. However, there is also an increase in sympathetic nervous activity by excitation of the muscle mechanoreceptors and metaboreceptors that contributes to the increase in heart rate, cardiac output, and systolic blood pressure (6). The blood pressure values during the execution of the resistance exercise were higher than the values found during the aerobic exercise.

The post-exercise hypotension is frequently reported in the literature following both aerobic (1,24) and resistance exercises (37). The mechanisms responsible for the reduction are
controversial, but apparently linked to the decrease in peripheral vascular resistance (20) and/or the decrease in cardiac output (35).

The present study did not evaluate other variables that would allow the findings to indicate whether these or other mechanisms were involved in the absence of hypotension. It is also important to note that although resistance exercise has demonstrated autonomic imbalance with decreased vagal and sympathetic predominance, this type of exercise promotes beneficial muscle adaptations that are important for the individual’s quality of life as well as a good performance in aerobic exercise (17).

Given this context, it is important to emphasize the possibility of evaluating the autonomic profile of individuals who are interested in engaging in a physical exercise program. The data from the autonomic modulation can help ensure a thorough understanding of the prescription and monitoring of physical training (25). In addition, the physiological behavior of the renal receptors during the different types, intensity, and duration of an exercise program is fundamental to increasing the safety and precision in prescribing regular exercise. In kidney recipients, in particular, baroreflex stabilizes after six months of kidney transplantation, thereby increasing the baroreflex sensitivity (26). Also, in kidney recipients, the autonomic nervous system has a better response in active kidney recipients compared to sedentary (16).

The two mechanisms crucial to controlling blood pressure in patients with renal failure are the mechanoreceptors and central command (33), while healthy individuals have a greater influence via the metaboreceptors post-exercise that decreases the acidosis more effectively. The main system that controls the SNS response during exercise is the central command, which increases the sympathetic activation in maximum and submaximal exercise. Also, the muscle ergoreflex increases sympathetic activation when stimulated during exercise by way of the metaboreceptors and mechanoreceptors (34).

The decrease in BRS may have also occurred due to an increase in cardiac output, venous return, and heart rate during the aerobic exercise. These increases are caused by vagal inhibition and consequent peripheral sympathetic activation (2). Possibly 60 min of rest was not sufficient for the baroreflex mechanism to be restored after the strength exercise. We propose for future studies in this population, making the collection with Finapress in more than a moment, primarily from 60 min post-exercise. Also, we consider a limitation of the study, the subjectivity of the Borg scale to rate the intensity of the strength exercise.

CONCLUSIONS

The findings indicate that the behavior of the autonomic system was re-established after the aerobic exercise. The same behavior did not occur with the strength exercise protocol. This information is important because autonomic recovery after exercise is an important index for long-term training periodization.
ACKNOWLEDGMENTS

We would like to thank Conselho Nacional de Desenvolvimento Científico e Tecnológico – CNPq (442374/2014-3) and Fundação de amparo à pesquisa do estado do Maranhão – FAPEMA (Nº 00358/15 and 40/2014 CM).

Address for Correspondence: Prof. Dr. Cristiano Mostarda, Av dos Portugueses, 1966, Physical Education Department, Federal University of Maranhão. Email: cristiano.mostarda@gmail.com

REFERENCES


**Disclaimer**

The opinions expressed in JEPonline are those of the authors and are not attributable to JEPonline, the editorial staff or the ASEP organization.