Effects of aerobic exercise on blood glucose in continuous ambulatory peritoneal dialysis patients

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ABSTRACT
Background: Peritoneal dialysis has a number of complications including increased blood glucose. Although exercise has been suggested to resolve this complication, most patients are not active. The present study aimed at determining the effects of twice-weekly, 40-min sessions of pedaling on a stationary bicycle on mean fasting blood sugar (FBS) and 2-h postprandial blood sugar (PPBS) among continuous ambulatory peritoneal dialysis patients.

Materials and Methods: In this clinical trial, convenience sampling was used to select 22 patients [age: 51.4 (12.3) years] undergoing continuous ambulatory peritoneal dialysis [mean duration: 12.5 (8.5) months] from university hospitals in Isfahan, Iran. The subjects were randomly divided into two groups (test and control). The test group participated in an 8-week exercise program in which they pedaled a stationary bicycle with an intensity of four on Borg Scale of Perceived Exertion. FBS and PPBS were measured at baseline and at the end of the 8th and 16th sessions of exercise. Data were analyzed with Student’s t-test and repeated measures analysis of variance.

Results: After the eighth session, the mean FBS and PPBS levels were lower in the test group than in the control group. However, the differences were not statistically significant. After 16 sessions of exercise, the mean FBS and PPBS levels in the intervention group were significantly less than the control group.

Conclusions: Forty minutes of pedaling on a stationary bicycle for two times a week can significantly reduce mean FBS and PPBS levels in continuous ambulatory peritoneal dialysis patients.

Key words: Aerobic exercise, blood glucose, continuous ambulatory peritoneal dialysis, Iran, nurses

INTRODUCTION
The global prevalence of end-stage renal disease is increasing and predicted to reach 1200 cases per million population by 2020. Iran is no exception, since the incidence of new cases of the disease increases at an annual rate of 22.6% with 4000 new cases reporting every year. In an individual with end-stage renal failure, renal function is lower than 10% of its normal value and kidney treatments (renal transplantation, hemodialysis, and peritoneal dialysis) are indispensable to save the patient’s life. Although these therapies can significantly increase patient survival, they may cause multiple complications.

Continuous ambulatory peritoneal dialysis is the most common type of peritoneal dialysis. In peritoneal dialysis, glucose is added to the dialysate to create a higher gradient during the process of osmosis. Since the peritoneum is a semipermeable membrane, 50-80% of the glucose is absorbed. Therefore, the peritoneal glucose concentration will increase to about 15-40 times its physiological level. This will not only increase blood glucose, but also lead to changes in the peritoneal membrane structure. Such changes include vasculopathy, thickening of the peritoneal membrane, and reduced ultrafiltration (a vital function in renal patients). Consequently, metabolic complications due to excessive calorie intake and the subsequent weight gain, and increased blood glucose are among the side effects of peritoneal dialysis. As the latter two complications, either alone or in combination, are found in 84% of peritoneal dialysis patients, metabolic control in these patients requires a comprehensive strategy.

As the resulting physical inactivity and exacerbation of cardiovascular problems account for a large proportion of mortality in dialysis patients, most researchers recommend exercise to reduce these side effects. While the researchers believe that exercise facilitates muscle glucose uptake and thus lowers blood glucose levels, the majority of patients undergoing peritoneal dialysis...
do not have physical activity and cannot enjoy improved glycemic control.\textsuperscript{14}

Lack of adequate encouragement for the patients, inaccessibility of sports sites.\textsuperscript{15} and problems caused by the pathophysiology of the disease are among the barriers to exercise.\textsuperscript{16} Despite the various obstacles to motivating patients to exercise,\textsuperscript{17} a proper exercise program will undoubtedly contribute to better control of their blood glucose levels. Numerous studies worldwide have evaluated the effects of exercise on blood pressure, heart function, adequacy of dialysis, quality of life, and urea and albumin levels in hemodialysis patients.\textsuperscript{18-20} They have mostly used training protocols including 30–60 min of pedaling on stationary bicycles for two to three times a week during courses of 6 weeks to 12 months. Borg Scale of Perceived Exertion is the most commonly employed method to determine exercise intensity.\textsuperscript{21}

Patients undergoing peritoneal dialysis refer to hospitals less frequently than do hemodialysis patients. It is thus more difficult to persuade the first group to attend a fitness center. This means that individual sports or exercises that can be done at home or workplace have to be considered in designing an exercise program for these patients.\textsuperscript{22} Moreover, these patients will need accessible, affordable, safe, and easy-to-use exercise equipment that suits their physical conditions.\textsuperscript{23} Accordingly, being small, safe, and portable makes stationary bicycle a good choice for individuals who cannot exercise outside their home. Pedaling on a stationary bicycle increases the patient’s aerobic capacity,\textsuperscript{13} while enabling him/her to constantly monitor his/her cardiac function and blood pressure during exercise. Besides, working out in a sitting position helps patients with orthopedic limitations, balance disorder, and orthostatic blood pressure change use the equipment.\textsuperscript{24}

Cycling and walking are both aerobic exercises. Research about the effects of aerobic exercise on blood glucose in diabetic patients has reported contradictory results. Shivananda et al. found that 6 weeks of aerobic exercise (walking on treadmill) significantly decreased fasting and 2-h postprandial blood glucose levels in diabetic patients.\textsuperscript{25} Similarly, Chiyan et al. showed 12 weeks of treadmill exercise to significantly decrease fasting blood glucose in continuous ambulatory peritoneal dialysis patients.\textsuperscript{26} In contrast, Micaus et al. reported that 7 days of treadmill exercise did not affect fasting blood glucose in type II diabetics.\textsuperscript{24}

In their attempt to control the complications of peritoneal dialysis, nurses are required to promote healthy lifestyle\textsuperscript{6} and encourage patients to exercise.\textsuperscript{16} However, few studies have assessed the effects of exercise on peritoneal dialysis patients. In addition, there is no agreement about a safe and accessible exercise for these patients.\textsuperscript{27} Considering the need for broader studies in this field,\textsuperscript{28} we consulted a nephrologist about the safety of stationary bicycles for the mentioned group of patients and designed a study to investigate the effects of aerobic exercise with this equipment on mean fasting and 2-h postprandial blood glucose levels in patients undergoing continuous ambulatory peritoneal dialysis.

**Materials and Methods**

This clinical trial was conducted for 2 months in 2011. After the research project was approved by the ethical committee of the university and research permission was issued in nursing and midwifery, sampling was started. A total of 22 continuous ambulatory peritoneal dialysis patients were selected from Alzahra and Ali Asghar hospitals (Isfahan, Iran) through convenience sampling. The inclusion criteria were: age above 18 years, at least 3 months of having undergone peritoneal dialysis,\textsuperscript{26} and being dialyzed with dialysates containing 1.5% glucose. Individuals with ischemic disease or diagnosis of angina in the past 6 months, pulmonary disease requiring oxygen therapy, stroke or transient ischemic attack within 3 months before the study, any musculoskeletal disorder preventing physical activity,\textsuperscript{13} blood pressure ≥ 180/110 mmHg or systolic blood pressure ≤ 90 mmHg,\textsuperscript{26} evidence of peritonitis, body temperature greater than 37.8°C,\textsuperscript{29} and diabetes were not included. Hospitalization for any reason, changes in the type of dialysate, symptoms suggestive of peritonitis, and receiving insulin or hypoglycemic tablets during the course of the study were the exclusion criteria.

The selected patients were explained about the objectives of the study and asked to sign written informed consent forms. Then, they were randomly divided into two groups of 11 each (test and control groups) (Table 1). The intervention group participated in an 8-week aerobic exercise program\textsuperscript{18} comprising two 40-min sessions of pedaling on an electric stationary bicycle (made in Taiwan) per week. The sessions were held between 8 a.m. and 12 p.m. in a quiet ventilated place with sufficient light while the patient had comfortable clothing on. Before each session, the patient relaxed on a chair with back support for 5 min. The spine was in neutral position and no pressure was exerted on the abdomen during this time. After blood pressure and temperature control, the exercise started only if blood pressure was less than 180/110 mmHg, systolic blood pressure was more than 90 mmHg, and temperature was less than 37.8°C.

The active phase of exercise (30 min of pedaling) was preceded and followed by 5 min of static stretching of lower extremities and adjusting the bicycle at 35 rounds
Results

All the 22 participants (11 in the test group and 11 in the control group) completed the study without any problem. The two groups had no significant differences in demographic characteristics including age, gender, duration of dialysis, and underlying cause of renal failure [Table 1].

At baseline, the mean (SD) FBS levels were 118.5 (9.0) mg/dl in the test group and 117.8 (15.5) mg/dl in the control group. The corresponding values were 108.2 (14.3) and 117.2 (15.1) mg/dl, respectively, after 8 sessions of exercise and 93.6 (12.5) and 117.4 (15.4) mg/dl, respectively, after 16 sessions (at the end of the study). While the mean FBS levels of the two groups were not significantly different either before the intervention \( (P = 0.910) \) or after the 8th session \( (P = 0.167) \), significantly lower levels were observed in the test group after the 16th session \( (P = 0.001) \) [Table 2].

In addition, there was no significant difference between the test and control groups in terms of 2-h PPBS at baseline \( [182.4 \ (26.7) \text{ mg/dl vs. } 183.2 \ (24.1) \text{ mg/dl}; \ P = 0.940] \) or after eight sessions \( [172.2 \ (21.4) \text{ mg/dl vs. } 181.9 \ (21.9) \text{ mg/dl}; \ P = 0.305] \). However, after 16 sessions of exercise, the 2-h PPBS level was significantly lower in the test group compared to the control group \( [162 \ (15.1) \text{ mg/dl vs. } 182.0 \ (18.6) \text{ mg/dl}; \ P = 0.010] \) [Table 2].

Within-group differences of FBS and 2-h PPBS levels are shown in Figures 1 and 2, respectively. As it is observed, the test group’s mean FBS had a decreasing trend from baseline to the 8th and then the 16th sessions \( (P = 0.001) \). In contrast, there were no significant differences between the values in the control group \( (P = 0.940) \) [Figure 1]. Similarly, the test group’s 2-h PPBS levels showed a significant reduction from baseline to the 8th session and from the 8th session to the 16th session \( (P = 0.006) \). However, no such significant change was detected in the control group \( (P = 0.910) \) [Figure 2].

### Table 1: Demographic and disease-related characteristics of continuous ambulatory peritoneal dialysis patients in the two groups

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Test group</th>
<th>Control group</th>
<th>( P )</th>
<th>Statistical test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female/male</td>
<td>2/9</td>
<td>3/8</td>
<td>0.50</td>
<td>Fisher’s exact test ( = 1 )</td>
</tr>
<tr>
<td>Age (years)</td>
<td>50.5 (14.3)</td>
<td>52.3 (10.3)</td>
<td>0.74</td>
<td>( t = 0.32 )</td>
</tr>
<tr>
<td>Duration of peritoneal dialysis (months)</td>
<td>12.1 (8.1)</td>
<td>13.0 (8.9)</td>
<td>0.77</td>
<td>( t = 0.29 )</td>
</tr>
<tr>
<td>Cause of renal failure</td>
<td></td>
<td></td>
<td>0.54</td>
<td>( \chi^2 = 4.98 )</td>
</tr>
<tr>
<td>Hypertension</td>
<td>5</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glomerulonephritis</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polycystic kidney</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urinary reflux</td>
<td>1</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Renal artery stenosis</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nephrotic syndrome</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>1</td>
<td>4</td>
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<td></td>
</tr>
</tbody>
</table>

Values are either number of participants or mean (SD)
**DISCUSSION**

We found no significant differences between the test and control groups in terms of the mean FBS and 2-h PPBS levels before the intervention. Moreover, the mean FBS and 2-h PPBS levels of the control group did not show significant changes throughout the study. In the test group, however, eight sessions of aerobic exercise could make statistically insignificant reductions in both the mentioned values. The reductions turned to be significant after the 16th session. Mikas et al. reported 7 days of aerobic exercise to have no significant effects on FBS levels and considered low number of sessions as the possible reason.\[24\] Generally, 40 min of pedaling on a stationary bicycle, twice weekly for 8 weeks is accepted to significantly lower FBS and 2-h PPBS levels in patients undergoing continuous ambulatory peritoneal dialysis. In a study on 16 patients undergoing continuous ambulatory peritoneal dialysis, Chi Yan et al. indicated that 12 weeks of treadmill workout significantly decreased the patients’ mean FBS from 95.4 ± 12.6 to 90 ± 10.8 mg/dl.\[26\]

Walking can also be effective in controlling blood sugar. In 2011, Ahmadi and Ghajari evaluated the effects of an 8-week course of walking on blood sugar levels of 20 patients with type II diabetes. At the end of the study, they identified the intervention group to have significantly lesser mean FBS and 2-h PPBS levels compared to the control group. They concluded that since working muscles are more sensitive to insulin, aerobic exercise facilitates glucose uptake by the muscles, and can thus be a definitive tool in blood glucose control.\[25\]

Ragers,\[31\] Bernard,\[32\] Baldy and Esnoling,\[33\] and Isfahani\[34\] showed that aerobic exercise (walking and bicycle riding) can help better to control blood sugar in patients with type II diabetes. They believed that aerobic exercise increases insulin binding to the receptors of monocytes, which in turn causes higher production of insulin and thus greater glucose absorption, and finally reduces the blood sugar level. On the contrary, Mikas et al. reported that 7 days of aerobic exercise (walking and stationary bicycling) could not significantly decrease FBS among the studied subjects.\[24\] Such an inconsistency might have been due to the difference in the number of subjects, duration of exercise, and exercise program designs. Hence, further research to assess the impact of longer periods of exercise on blood sugar levels is warranted.

In continuous ambulatory peritoneal dialysis patients, impaired glucose metabolism is seen in the form of glucose intolerance, decreased peripheral insulin sensitivity, hyperinsulinemia, and hyperglycemia. Both hyperinsulinemia and hyperglycemia increase the risk of diabetics. At the end of the study, they identified the intervention group to have significantly lesser mean FBS and 2-h PPBS levels compared to the control group. They concluded that since working muscles are more sensitive to insulin, aerobic exercise facilitates glucose uptake by the muscles, and can thus be a definitive tool in blood glucose control.\[25\]

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**Table 2: Comparison of the mean FBS and 2-h PPBS at baseline and after 8 and 16 sessions of aerobic exercise in the test and control groups**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Groups</th>
<th>Mean</th>
<th>SD</th>
<th>P</th>
<th>Variable</th>
<th>Groups</th>
<th>Mean</th>
<th>SD</th>
<th>P</th>
<th>Variable</th>
<th>Groups</th>
<th>Mean</th>
<th>SD</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>FBS (mg/dl)</td>
<td>Test</td>
<td>118.0</td>
<td>9.0</td>
<td>0.91</td>
<td>FBS (mg/dl)</td>
<td>Test</td>
<td>108.0</td>
<td>14.3</td>
<td>0.167</td>
<td>FBS (mg/dl)</td>
<td>Test</td>
<td>93.6</td>
<td>12.5</td>
<td>0.001</td>
</tr>
<tr>
<td>Control</td>
<td>117.0</td>
<td>15.5</td>
<td></td>
<td></td>
<td>Control</td>
<td>117.0</td>
<td>15.1</td>
<td></td>
<td></td>
<td>Control</td>
<td>117.0</td>
<td>15.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PPBS (mg/dl)</td>
<td>Test</td>
<td>182.0</td>
<td>26.7</td>
<td>0.94</td>
<td>PPBS (mg/dl)</td>
<td>Test</td>
<td>172.0</td>
<td>21.4</td>
<td>0.305</td>
<td>PPBS (mg/dl)</td>
<td>Test</td>
<td>162.0</td>
<td>12.5</td>
<td>0.01</td>
</tr>
<tr>
<td>Control</td>
<td>183.0</td>
<td>24.1</td>
<td></td>
<td></td>
<td>Control</td>
<td>181.0</td>
<td>21.9</td>
<td></td>
<td></td>
<td>Control</td>
<td>182.0</td>
<td>18.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FBS: Fasting blood sugar, PPBS: Postprandial blood sugar, SD: Standard deviation

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**Figure 1:** FBS of the subjects at baseline and after 8 and 16 sessions of aerobic exercise

**Figure 2:** Two-hour PPBS at baseline and after 8 and 16 sessions of aerobic exercise
aerobic exercises. Exercise is one among the interventions to control weight, blood lipids, and blood sugar in these patients. Research has confirmed that exercise enhances the capillary bed and increases the number of insulin receptors. Since working muscles are more sensitive to insulin than resting muscles, each unit of insulin will cause more glucose absorption during exercise. This reduces blood sugar, especially in mild- to moderate-intensity exercises. Thus, aerobic exercises, which are safe and easy, can increase insulin sensitivity, decrease insulin resistance, lower blood sugar, and ultimately improve the quality of life in continuous ambulatory peritoneal dialysis patients. As nursing care for these patients aims to reduce metabolic complications, nephrologists and nurses in peritoneal dialysis units are required to examine patients and encourage those without contraindications to get involved in safe exercises (such as pedaling on a stationary bicycle) in the peritoneal dialysis units, at home, and even at work.

**CONCLUSION**

According to the results of this study, aerobic exercise (pedaling on a stationary bicycle) can significantly decrease FBS and 2-h PPBS levels in continuous ambulatory peritoneal dialysis patients. Hence, nurses can help these patients prevent treatment complications by encouraging them to exercise. However, since small sample size in the present study limits the generalizability of the results, future studies in this field are suggested to use larger sample size and longer duration of intervention with other types of safe aerobic exercises.

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