Aerobic exercise capacity and pulmonary function in athletes with and without type 1 diabetes mellitus

William R Komatsu, MS; Turibio L Barros Neto, MD, PhD; Antonio R Chacra, MD, PhD; Sergio A Dib, MD, PhD

Diabetes Center, Department of Medicine, Endocrinology Division and Physical Activity and Sports Medical Center, Federal University of São Paulo, São Paulo, Brazil

Corresponding author:
William R Komatsu
Email: william.komatsu@unifesp.br

Submitted 28 April 2010 and accepted 24 August 2010.

This is an uncopyedited electronic version of an article accepted for publication in Diabetes Care. The American Diabetes Association, publisher of Diabetes Care, is not responsible for any errors or omissions in this version of the manuscript or any version derived from it by third parties. The definitive publisher-authenticated version will be available in a future issue of Diabetes Care in print and online at http://care.diabetesjournals.org.
Objective - To compare the aerobic exercise capacity and pulmonary function between athletes with and without type 1 diabetes mellitus.

Research design and methods - Fifty-one adult age-matched individuals were assessed in random order to VO\textsubscript{2peak max} (ml/kg/min), anaerobic threshold (ml/kg/min), peak VE (btps) and heart rate (beats/min), time to exhaustion (min), FVC(%), FEV1(%), TLC(%), and DLCO(%). Individuals were 27 T1DM 15 athletes (ADM) and 12 non-athletes (NADM) and 24 healthy individuals 12 athletes and 12 non-athletes. Duration of diabetes was 14.6±6.2 and 15.2±6.7 years respectively in ADM and NADM.

Results - VO\textsubscript{2peak max} was higher in the athletes than in non-athletes (p<0.001). The anaerobic threshold was lower in T1DM than in controls (p<0.001). FEV1 was lower in ADM than in other groups (NADM, AC and NAC p<0.001).

Conclusion - Aerobic capacity in T1DM with programmed exercise are similar to those of normal athletes, despite lower anaerobic threshold and FEV1.
All individuals were in a non-fasting state and the diabetic group two hours after their last routine insulin injection.

Aerobic exercise capacity was conducted using a motorized Life Fitness treadmill model 9100 HR (Schiller Park, IL, USA). A metabolic system model assembled together with a CO₂/O₂ gas analyzer (Vista Mini CPX, VacuMed Turbofit, Ventura, CA, USA) was used to determine the subject’s aerobic power (peak VE<sub>max</sub>).

The test ended (subject showed signs or symptoms of fatigue) at what we considered the VO<sub>2peakmax</sub>(ml/kg/min) of oxygen consumption (aerobic exercise capacity). O₂ consumption, CO₂ production, and VE were monitored at 30s intervals. The VO<sub>2peak max</sub> was used to define the subject’s aerobic capacity. Anaerobic threshold was measured when VE and VCO₂ began to increase non-linearly as compared to VO₂ (9).

The time and the flow-volume [lung dynamic and static volumes curves (Collins spirometer DS11a; Warren E. Collins, Inc., MA, USA)] and DL<sub>CO</sub> were obtained following the American Thoracic Society Pulmonary Function Test Guidelines (10). Forced vital capacity (FVC) and expiratory volume in the first second (FEV₁), functional residual capacity (FRC) (open-circuit method of N₂ washout), and DL<sub>CO</sub> (corrected for individual hemoglobin concentrations) measurements were reported. Inspiratory volumes were considered acceptable when subjects achieved an inspired volume above 90% of their vital capacity in all tests. All spirometric, N₂ wash-out and DL<sub>CO</sub> data are reported as percentages of the normal predicted values by age, height and sex.

**Statistical analysis.** Statistical analysis was performed using the SPSS 17.0 (Chicago, IL). The variable curve normality was evaluated using the Kolmogorov–Smirnov test. The correlation (Spearman or Pearson coefficients) between variables was accomplished using the ANOVA test and a Tukey post-hoc analysis. P < 0.05 was considered significant.

**RESULTS**

The anthropometric parameters were similar between the T1DM and control groups. The HbA₁c was higher in the NADM than in the ADM (9.0 ± 1.3 vs. 7.5 ± 6.2%; p< 0.05). There were no statistical differences in the MA between diabetic groups.

The VO<sub>2peakmax</sub> was higher in the ADM (42.4 ± 5.5 ml/kg/min) and AC (44.2 ± 5.0) than in the NADM (34.8 ± 3.3) and NAC (37.8 ± 2.7; p<0.001). Anaerobic threshold was lower in the ADM (31.7 ± 4.4 ml/kg/min) and NADM (24.6 ± 3.3) than in the AC (35.9 ± 4.9) and NAC (28.3 ± 3.0) (p<0.001). FEV₁ in AC (102 ± 0.6 %) and NAC (97 ± 0.4%) was higher than in the ADM (89 ± 0.5%; p<0.001) (Table 1).

**CONCLUSIONS**

In this study, we have shown that T1DM athletes have a VO<sub>2peakmax</sub> similar to that of non-diabetic athletes but a lower anaerobic threshold than that of non-diabetic athletes.

In a previous study, we demonstrated that non-athlete T1DM patients have a lower VO<sub>2peakmax</sub> than normal subjects (6). In the present study, we confirm these data in non-athlete T1DM patients, but that defect (low VO<sub>2peakmax</sub>) was not found in T1DM athletes. These data are in accordance with a study (11) that compared 128 patients with long-duration T1DM and 36 healthy individuals.
Metabolic issues (such as hyperglycemia and low lactic acid clearance during and after exercise) and respiratory problems (the ventilation reached at peak exercise is lower in proportion to their reduction in O₂ uptake) may relate to reduced anaerobic threshold and early fatigability or loss of performance (12). However, we did not find a difference in VO₂peakmax between T1DM and normal control athletes. Therefore, other factors besides ventilation may influence anaerobic threshold in this diabetic condition.

All of the individuals in this study went to heart rate max frequency during the test. However, the T1DM sedentary group had lower max HR than the control group, as expected. This was an interesting finding and one in accordance with our previous data (6), in which the diabetic group showed lower max frequency during exercise than normal controls. This defect could be corrected with regular exercise since the diabetic athlete was able to achieve the same max HR as a normal athlete.

In this study, we found also that FEV1 was decreased in T1DM athletes compared to other groups. This result conflicts with data found in T1DM non-athletes with the same clinical characteristics and duration of T1DM but higher HbA1c than T1DM athletes (13). However, this can suggest a difficult bronchial adaptation to air flow in the first second of expiration in these individuals. Abnormalities in lung elasticity behavior can be manifestations of widespread elastin and collagen abnormalities in T1DM patients (14). These alterations have been demonstrated in diabetes and are, in some respects, similar to those that occur during normal aging.

Author Contributions - W.K. researched data and wrote manuscript, T.B. researched data, A.C reviewed manuscript and S.D contributed to discussion, reviewed/edited manuscript.

ACKNOWLEDGMENTS
No potential conflicts of interest relevant to this article were reported. The authors wish to thank the study patients and volunteers and their families, as well as the staff of the Centre of Diabetes – UNIFESP. We thank to Professor Jose Roberto Jardim of Pneumology Division of São Paulo Federal University to his comments during this study. This study had the financial support of Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) of Brazilian Ministry of Education.

REFERENCES
Table 1. Anthropometrics, Clinical Characteristics, Physical capacity parameters and lung function in the subjects studied

<table>
<thead>
<tr>
<th></th>
<th>ADM (n=15)</th>
<th>NADM (n=12)</th>
<th>AC (n=12)</th>
<th>NAC (n=12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>27.4 ± 5.1</td>
<td>26.5 ± 5.6</td>
<td>27.7 ± 4.0</td>
<td>24.1 ± 5.0</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>70.4 ± 9.2</td>
<td>63.1 ± 9.0</td>
<td>68.0 ± 11.3</td>
<td>65.1 ± 11.2</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>174.5 ± 8.2*</td>
<td>164.4 ± 5.8 *∞</td>
<td>172.6 ± 7.1</td>
<td>171.0 ± 7.5</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>23.0 ± 1.7</td>
<td>23.3 ± 2.8</td>
<td>22.6 ± 2.4</td>
<td>22.1 ± 2.6</td>
</tr>
<tr>
<td>TDDM (years)</td>
<td>14.6 ± 6.2</td>
<td>15.2 ± 6.7</td>
<td>-----------</td>
<td>-----------</td>
</tr>
<tr>
<td>HbA1c (%)</td>
<td>7.5 ± 6.2 *†</td>
<td>9.0 ± 1.3 *∞ ×</td>
<td>4.4 ± 0.8 †∞</td>
<td>4.4 ± 0.8 †√</td>
</tr>
<tr>
<td>Microalbuminuria (µg/min)</td>
<td>10.46 ± 7.2†Ω</td>
<td>11.69 ± 7.53∞×</td>
<td>2.75 ± 3.01†∞</td>
<td>4.44 ± 3.19Ω×</td>
</tr>
<tr>
<td>VO2peak max (ml/kg/min)</td>
<td>42.4 ± 5.5†×</td>
<td>34.8 ± 3.3*∞</td>
<td>44.2 ± 5.0∞°</td>
<td>37.8 ± 2.7°×</td>
</tr>
<tr>
<td>Anaerobic threshold (ml/kg/min)</td>
<td>31.7 ± 4.4†Ω</td>
<td>24.6 ± 3.3*∞ ×</td>
<td>35.9 ± 4.9†∞°</td>
<td>28.3 ± 3.0Ω× ×</td>
</tr>
<tr>
<td>Peak VEmax (btps)</td>
<td>101.8 ± 21.8</td>
<td>91.2 ± 14.3∞</td>
<td>115.8 ±13.3∞</td>
<td>100.4 ± 8.8</td>
</tr>
<tr>
<td>Peak heart rate (beats/min)</td>
<td>194.2 ± 7.1</td>
<td>190.1 ± 6.4 ∞</td>
<td>198.0 ± 4.9∞°</td>
<td>192.5 ± 6.9°</td>
</tr>
<tr>
<td>Time to exhaustion (min)</td>
<td>13.3 ± 1.5Ω</td>
<td>12.4 ± 1.0∞</td>
<td>13.6 ± 1.2=∞°</td>
<td>12.1 ± 0.8Ω×</td>
</tr>
<tr>
<td>FVC (%)</td>
<td>89 ± 0.74</td>
<td>94 ± 0.86</td>
<td>99 ± 0.98</td>
<td>87 ± 0.24</td>
</tr>
<tr>
<td>FEV1 (%)</td>
<td>89 ± 0.51†Ω</td>
<td>96 ± 0.12</td>
<td>102 ± 0.68†</td>
<td>97 ± 0.47Ω</td>
</tr>
<tr>
<td>TLC (%)</td>
<td>100 ± 0.77</td>
<td>91 ± 0.78</td>
<td>101 ± 0.14</td>
<td>93 ± 0.99</td>
</tr>
<tr>
<td>DLCO (%)</td>
<td>101 ± 0.13</td>
<td>94 ± 0.76</td>
<td>103 ± 0.12</td>
<td>96 ± 0.64</td>
</tr>
</tbody>
</table>

Means ± SD. TDDM: time from diabetes diagnosis; VO₂, maximal oxygen consumption; VE, pulmonary ventilation; FVC, forced vital capacity; FEV₁, forced expiratory volume in 1 second; TLC, total lung capacity; DLCO, lung diffusion capacity for carbon monoxide.

Height: *ADMxNADM, ±NADM x AC
HbA1c: *ADMxNADM, †ADM x AC, ∆ADM x NAC, ‡NADM x AC, ×NADM x NAC,
Microalbuminuria: †ADM x AC, ∆ADM x NAC, ×NADM x NAC
VO₂ peak max: *ADMxNADM, †ADM x AC, ∆ADM x NAC, ×NADM x NAC
Anaerobic threshold: *ADMxNADM, †ADM x AC, ‡NADM x AC, ∆ACxNAC
Peak VE max: ∆NADM x AC
Peak heart rate: =NADM x AC, ‡ACxNAC
Time to exhaustion: †ADM x NAC, °NADM x AC, ‡ACxNAC
FEV₁: †ADM x AC, ∆ADM x NAC

The mean difference is significant at the 0.05 level