Cardiopulmonary exercise test in type 2 diabetes mellitus in absence of chronic heart failure: reduced lung and heart function

Avaliação cardiopulmonar em portadores de diabetes melitus tipo 2 sem doença cardíaca: redução da função cardiorespiratória


ABSTRACT: Was compared exercise tolerance, respiratory and cardiovascular functions between non-diabetics and type 2 diabetes individuals (T2DM) without chronic heart failure. Thirteen normaglycemic men (non-diabetic group – NDG) and eight T2DM (diabetic group – DG) performed a cardiopulmonary exercise test (CPX) on motor treadmill (test initiated at 3 km.h⁻¹ with an increment of 1 km.h⁻¹ every two minutes) to evaluate respiratory function, cardiovascular parameters and exercise tolerance. Workload and oxygen uptake (O₂) values at ventilatory threshold were significantly lower for DG (DG: 5.6 ± 0.5 km.h⁻¹ and 13.1 ± 3.8 mL.(kg.min⁻¹); NDG: 6.5 ± 0.5 km.h⁻¹ and 16.4 ± 2.8 mL.(kg.min⁻¹); p < 0.05). Peak O₂ and workload were significantly lower for DG (22.7 ± 5.7 mL.(kg.min⁻¹)-1;8.2 ± 0.7 km.h⁻¹) when compared with NDG (30.8 ± 5.4 mL.(kg.min⁻¹)-1; 11.6 ± 1.5 km.h⁻¹). Oxygen uptake efficiency slope (OUES) and circulatory power were significantly lower (p < 0.05) in DG, although no significant alterations were found in functional capacity and ventilatory efficiency. T2DM in absence of chronic heart failure presented exercise intolerance and lower cardiorespiratory fitness. Peak circulatory power and OUES were also reduced in these individuals.

Key Words: Maximal incremental test; Ventilatory efficiency; Circulatory power; Oxygen uptake efficiency slope and maximum oxygen uptake.

RESUMO: Foi comparar a tolerância ao exercício, funções respiratória e cardiovascular entre indivíduos não diabéticos e diabéticos tipo 2 sem doenças crônicas cardíacas. Treze homens normoglicêmicos (NDG) e oito homens diabéticos tipo 2 (DG) que realizaram um teste cardiopulmonar de esforço (TCPE) em uma esteira motorizada (o teste iniciou-se em 3km.h⁻¹ com incremento de 1km.h⁻¹ a cada dois minutos) que avaliou a função respiratória, parâmetros cardiovasculares e tolerância ao exercício. Valores de consumo de oxigênio e intensidades na intensidade do limiar ventilatório foram significativamente menores para o DG (DG: 5.6 ± 0.5 km.h⁻¹ e 13.1 ± 3.8 mL.(kg.min⁻¹); NDG: 6.5 ± 0.5 km.h⁻¹ e 16.4 ± 2.8 mL.(kg.min⁻¹); p < 0.05). Consumo de oxigênio pico e intensidade associada foram significativamente menores para o DG (DG: 22.7 ± 5.7 mL.(kg.min⁻¹)-1;8.2 km.h⁻¹) quando comparado com o NDG (30.8 ± 5.4 mL.(kg.min⁻¹)-1; 11.6 ± 1.5 km.h⁻¹). Consumo de oxigênio pico e intensidade associada foram significativamente menores para o DG (DG: 22.7 ± 5.7 mL.(kg.min⁻¹)-1;8.2 km.h⁻¹) quando comparado com o NDG (30.8 ± 5.4 mL.(kg.min⁻¹)-1; 11.6 ± 1.5 km.h⁻¹). Consumo de oxigênio pico e intensidade associada foram significativamente menores para o DG (p < 0.05) embora não foram encontradas diferenças significativas na eficiência ventilatória. Em indivíduos portadores de diabetes tipo 2, mesmo sem a presença conhecida de doenças cardiovasculares, apresentaram menores níveis de condicionamento cardiorespiratório e tolerância ao exercício. Circulatory power pico e OUES também foram reduzidos nesses indivíduos.

Palavras-chave: Teste incremental máximo; Eficácia ventilatória; Consumo máximo de oxigênio.
Introdução

Individuos com diabetes tipo 2 (T2DM) apresentam baixa condicionamento cardiovascular (CC) quando comparados com indivíduos não diabéticos1 e têm um aumento significativo da morbidade quando associados a falência cardíaca2-4. Além disso, controle glicêmico pobre está associado a risco aumentado de falência cardíaca5,6. No sistema respiratório, a membrana alveolocapilar é alvo de doenças coexistentes. A disfunção ventricular esquerda causa estresse hidrostático na membrana7 e a diabetes altera a camada basal da lâmina alveolar e da capilar pulmonar8, o que resulta em depressão sinergética da condutância da membrana e troca gaseosa9. Essas alterações, tanto na falência cardíaca quanto na função respiratória, influenciam o consumo máximo de oxigênio (VO2peak) e o limiar anaeróbio. Kunitomi et al.10 e Sales et al.11 evidenciaram que os pacientes com diabetes apresentaram VO2peak e VO2at limiar anaeróbio mais baixos e taxa de trabalho associado com essas características quando comparados com homens saudáveis.

Infelizmente, mudanças leves relacionadas a função pulmonar anormal geralmente são silenciosas em repouso, com 60% dos adultos diabéticos apresentando uma função pulmonar anormal, devido a uma transferência de gases anormal que pode resultar em valores mais baixos de VO2peak1-6. Nessa direção, o exercício máximo durante o test de exercício cardiorrespiratório (CPX), que é o padrão-ouro para avaliações não invasivas de parâmetros cardiorrespiratórios e fornece informações valiosas para diferentes populações relacionadas à função respiratória16,19. Entre os parâmetros ventilatórios, VO2peak e a relação ventilação/produção de dióxido de carbono (VE/CO2) são comumente preditores para mortalidade geral ou risco de stratificação. Esses parâmetros, avaliados de forma simples através de um CPX realizado em um consultório médico, são tipicamente associados a doenças cardiovasculares e respiratórias, especialmente com falência cardíaca crônica20-22.

A partir dessas considerações, alguns mecanismos pulmonares envolvidos na intolerância ao exercício em pacientes com falência cardíaca crônica23 podem explicar a redução de função pulmonar e capacidade de exercício em pacientes com T2DM8. No entanto, sobreventilação e hiperglicemia durante a atividade física, que são potencializadas pelo diabetes9, podem precipitar uma redução de função respiratória e cardiovascular, mesmo em ausência de falência cardíaca crônica.

Portanto, o objetivo da presente pesquisa foi comparar a tolerância ao exercício, a função respiratória e cardiovascular entre indivíduos não diabéticos e T2DM sem falência cardíaca crônica por meio de um CPX não invasivo. Portanto, a hipótese é que o grupo de pacientes diabéticos apresentarão intolerância ao exercício e redução de função pulmonar e cardiovascular.

Materiais e métodos

Participantes

Este estudo incluiu 21 homens sedentários. Treze normoglicêmicos (grupo não diabético – NDG) e oito diabéticos tipo 2 (grupo diabético – DG) diagnosticados através da glicose hemoglobina (HbA1c) > 6,5% e glicemia de jejum > 126 mg/dL, de acordo com as recomendações da American Diabetes Association e American College of Sports Medicine24,25. Os participantes diabéticos foram recrutados por telefone de uma lista que foi liberada pela Unidade de Saúde Escola (USE) da Universidade Federal de São Carlos. Os participantes normoglicêmicos foram empregados da Universidade de São Paulo e contatados por e-mail disponibilizado pela seção de creche da instituição.

A clínica foi realizada por um clínico (cardiologista) antes do início da presente pesquisa. A avaliação consistiu em anamnese e eletrocardiografia em repouso. O sangue foi coletado para determinar glicose, hemoglobina glicosilada, triglicíridos, colesterol e lipoproteínas de baixa e alta densidade (LDL e HDL). Os participantes com pressão arterial sistólica e diastólica > 160/100 mmHg, história de eventos cardiovasculares, alterações de função cardíaca detectadas e alterações pulmonares detectadas pelo espirometria, nefropatia, microalbuminúria e limitações artroarticulares, identificadas previamente por um clínico24, não foram incluídos. No grupo de pacientes diabéticos, seis participantes foram diagnosticados com hipertensão arterial sistêmica e três com doença coronariana, não foram incluídos. No grupo de pacientes diabéticos, seis participantes foram diagnosticados com hipertensão arterial sistêmica e três com doença coronariana, foram incluídos. Todas as participantes e participantes foram informatizados e consentiram antes de cada participante e foram assinados um consentimento informado, que foi aprovado pelo institucional Human Subject Review Board (protocolo n. 0042011). O protocolo experimental foi condizente com o Conselho Nacional de Ética de Pesquisa no Brasil (protocolo n. 466-12/12).
Experimental design

After clinical examination, participants performed three visits to the laboratory: 1) interview and application of international physical activity questionnaire (IPAQ) short version; anthropometric, hemodynamic and biochemical measurements; 2) familiarization with the equipment and protocol; 3) CPX to evaluate respiratory function, cardiovascular parameters and exercise tolerance. Visits were separated by at least 48 hours and maximum of one week. Subjects were instructed not to perform strenuous exercise or ingest alcoholic and/or caffeinated beverages within 24 hours before each visit.

Anthropometric and hemodynamic evaluations

Body mass and composition were determined using a tetra polar bioelectric impedance system with electrodes in contact with soles and heels of both feet and hands (Tanita BC-558 Ironman Segmental Body Composition Monitor bioelectrical impedance scale). The measurements were performed in a quiet environment after a 12 h overnight fast, with subjects in standing position using light clothes, without shoes.

Blood pressure assessment were conducted in accordance with the VII Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure guidelines, which recommends a seated position with uncrossed legs, feet flat on the floor, and left arm supported at heart level. Blood pressure was measured after 10 min of rest with a calibrated automated blood pressure device (G-TECH® BP3AA1-H, Genexel Medical Instruments, South Korea).

Rest biochemical analysis

Approximately 5 ml blood was drawn from antecubital vein by venous puncture and allocated in a EDTA tube. High Performance Liquid Chromatography technique was used to analyze HbA1c. Total cholesterol, triglycerides and fasting plasma glucose were analyzed by spectrophotometry.

Cardiopulmonary exercise testing

The CPX was performed on motor treadmill at 3 km/h with an increment of 1 km/h every two minutes, the treadmill grade remained in 0% during all procedure. The protocol continued until the volunteer reached the volitional fatigue or leg discomfort. Ventilatory parameters were collected by a medium pneumotachometer (6 – 120 L/min) and continuously measured by a previously calibrated gas analyzer (VO2000, Medgraphics, St. Paul, Minnesota, USA). The gas analyzer was calibrated accordingly to the fabricant’s guidelines.

Ventilatory, metabolic and cardiovascular measures

The following data were assessed on 20 seconds average: $\dot{V}O_2$ and carbon dioxide production ($\dot{V}CO_2$) at standard temperature and pressure, containing no water vapour (STPD) and the minute ventilation ($\dot{V}E$) at body temperature and ambient pressure, saturated with water vapour (BTPS).

Peak $\dot{V}O_2$ was the highest $\dot{V}O_2$ value during the exercise test and peak workload was the running velocity elicited at peak $\dot{V}O_2$. Peak respiratory exchange ratio (RER) was the average of 20-s $\dot{V}CO_2$, divided by $\dot{V}O_2$. $O_2$ pulse (mL/beat) was determined dividing peak $\dot{V}O_2$ (mL/min) by maximal HR (bpm). $\dot{V}O_2$ and workload at ventilatory threshold (VT) were measured by V-slope method. Resting VE, $\dot{V}O_2$ and RER were expressed as a 1-min resting averaged value.

Ventilatory efficiency was measured by plotting $\dot{V}E$ against $\dot{V}CO_2$ and during exercise is represented by the slope of all $\dot{V}E$/$\dot{V}CO_2$ values during CPX excluding nonlinear portion of this relationship after VT. Oxygen uptake efficiency slope (OUES), an index that measures cardiorespiratory functional reserve, was calculated using log-transformation (base 10) of $\dot{V}E$ by $\dot{V}O_2$; both variables, log$\dot{V}E$ and $\dot{V}O_2$, used to calculate the OUES were in L/min, as suggested by Sperling et al. and Baba et al. Circulatory power was defined as the product of peak $\dot{V}O_2$ and peak systolic blood pressure. Ventilatory power was defined as peak systolic blood pressure divided by the VE/VCO2 slope.
Blood samples (25 µL) were collected from the earlobe at rest and immediately after CPX for blood lactate concentration (BLC) analysis. Blood samples were collected in heparinized capillaries previously calibrated and stored in Eppendorf® tubes with 50-µL sodium fluoride 1%. BLC was analyzed using electroenzymatic method with a lactate analyzer (1500 Sport; Yellow Springs Instruments Inc., Yellow Springs, OH, USA). Heart rate was measured at rest and during CPX using a heart rate monitor (Polar® Si 810, Kemple, Finland). Predicted maximal heart rate was determined by the equation 220 – age. Blood pressure was obtained immediately at the end of CPX.

<table>
<thead>
<tr>
<th></th>
<th>NDG</th>
<th>DG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>51.5 ± 5.8</td>
<td>55.4 ± 7.0</td>
</tr>
<tr>
<td>Diabetes time, years</td>
<td>-</td>
<td>6.0 ± 4.3</td>
</tr>
<tr>
<td>Height, cm</td>
<td>172.3 ± 7.3</td>
<td>170.0 ± 7.8</td>
</tr>
<tr>
<td>Body mass, kg</td>
<td>80.8 ± 11.7</td>
<td>92.8 ± 9.4*</td>
</tr>
<tr>
<td>Body mass index, kg/m²</td>
<td>27.2 ± 3.2</td>
<td>32.2 ± 3.2*</td>
</tr>
<tr>
<td>HbA1c, %</td>
<td>5.19 ± 0.48</td>
<td>9.35 ± 2.14*</td>
</tr>
<tr>
<td>Fasting glucose, mg/dL</td>
<td>97.8 ± 18.2</td>
<td>191.9 ± 55.1*</td>
</tr>
<tr>
<td>Total cholesterol, mg/dL</td>
<td>223.5 ± 48.1</td>
<td>206.1 ± 34.3</td>
</tr>
<tr>
<td>Triglycerides, mg/dL</td>
<td>145.4 ± 54</td>
<td>192.1 ± 86.9</td>
</tr>
<tr>
<td>Fructosamine, μmol/L</td>
<td>-</td>
<td>276.5 ± 69.6</td>
</tr>
<tr>
<td>Resting HR, bpm</td>
<td>72.7 ± 8.6</td>
<td>78.7 ± 11.1</td>
</tr>
<tr>
<td>Resting SBP, mmHg</td>
<td>116.9 ± 12.8</td>
<td>135.7 ± 16.9*</td>
</tr>
<tr>
<td>Resting DBP, mmHg</td>
<td>74.9 ± 7.2</td>
<td>82.5 ± 8.9*</td>
</tr>
</tbody>
</table>

HbA1c, glycated hemoglobin; HR, heart rate; SBP, systolic blood pressure; DBP, diastolic blood pressure; * p < 0.05 for NDG.

Statistical analysis
Data were expressed as mean ± standard deviation (SD). Shapiro–Wilk’s normality test was used to test data normal distribution. The variables analyzed in the study presented normal distribution. Independent-samples t-test was used to compare the differences between DG and NDG. Significance was assumed when p ≤ 0.05 and SPSS version 20.0 (Somers, NY, USA) software was used.

Results
Anthropometric, hemodynamic and biochemical characteristics are summarized in table 1. Baseline fasting glucose, HbA1c, blood pressure, BMI and weight were significantly higher (p < 0.05) for DG.

Table 2 shows that DG had significantly lower resting $\dot{V}O_2$ values and higher baseline BLC. Workload and $\dot{V}O_2$ values at ventilatory threshold and peak exercise were significantly lower) for DG. Mean cardiopulmonary values indicate that groups had preserved functional capacity and ventilatory efficiency, however, OUES and circulatory power were significantly lower in DG.
Table 2. Cardiopulmonary exercise test parameters in diabetic (DG) and non-diabetic (NDG) groups (mean ± SD).

<table>
<thead>
<tr>
<th></th>
<th>NDG</th>
<th>DG</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rest</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VE, L/min</td>
<td>7.3 ± 2.7</td>
<td>6.1 ± 2.9</td>
</tr>
<tr>
<td>VO₂, mL.(kg.min⁻¹)</td>
<td>3.3 ± 1.6</td>
<td>2.0 ± 0.8*</td>
</tr>
<tr>
<td>RER</td>
<td>0.96 ± 0.19</td>
<td>1.03 ± 0.11</td>
</tr>
<tr>
<td>Lactate, mmol/L</td>
<td>1.4 ± 0.6</td>
<td>2.2 ± 0.6*</td>
</tr>
<tr>
<td><strong>Ventilatory threshold</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Workload, km/h</td>
<td>6.5 ± 0.5</td>
<td>5.6 ± 0.5*</td>
</tr>
<tr>
<td>VO₂, mL.(kg.min⁻¹)</td>
<td>16.4 ± 2.8</td>
<td>13.1 ± 3.8*</td>
</tr>
<tr>
<td>%VO₂ peak</td>
<td>53.5 ± 7.4</td>
<td>60.3 ± 18.5</td>
</tr>
<tr>
<td><strong>Peak</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart rate, bpm</td>
<td>164.7 ± 10.5</td>
<td>151.4 ± 21.0</td>
</tr>
<tr>
<td>Predcted maximal heart rate, %</td>
<td>98.1 ± 6.1</td>
<td>90.7 ± 10.3</td>
</tr>
<tr>
<td>SBP, mmHg</td>
<td>173.9 ± 25.5</td>
<td>183.7 ± 20.7</td>
</tr>
<tr>
<td>DBP, mmHg</td>
<td>75.7 ± 9.9</td>
<td>73.7 ± 13.0</td>
</tr>
<tr>
<td>Workload, km/h</td>
<td>11.6 ± 1.5</td>
<td>8.2 ± 0.7*</td>
</tr>
<tr>
<td>VE, L/min</td>
<td>63.1 ± 11.9</td>
<td>63.2 ± 16.2</td>
</tr>
<tr>
<td>VO₂, mL.(kg.min⁻¹)</td>
<td>30.8 ± 5.4</td>
<td>22.7 ± 5.7*</td>
</tr>
<tr>
<td>RER</td>
<td>1.20 ± 0.11</td>
<td>1.34 ± 0.08*</td>
</tr>
<tr>
<td>O₂ pulse, mL/beats</td>
<td>14.6 ± 2.3</td>
<td>15.1 ± 0.7</td>
</tr>
<tr>
<td>Lactate, mmol/L</td>
<td>7.2 ± 2.1</td>
<td>7.1 ± 1.5</td>
</tr>
<tr>
<td>VE/VCO₂ slope</td>
<td>17.5 ± 1.0</td>
<td>18.7 ± 2.9</td>
</tr>
<tr>
<td>OUES</td>
<td>2.67 ± 0.48</td>
<td>2.12 ± 0.50*</td>
</tr>
<tr>
<td>Circulatory power, mmHg.mL.(kg.min⁻¹)</td>
<td>5313 ± 967</td>
<td>4105 ± 913*</td>
</tr>
<tr>
<td>Ventilatory power, mmHg</td>
<td>3044 ± 518</td>
<td>3345 ± 766</td>
</tr>
</tbody>
</table>

VE, minute ventilation; VO₂, oxygen uptake; RER, respiratory exchange ratio; SBP, systolic blood pressure; DBP, diastolic blood pressure; OUES, oxygen uptake efficiency slope; * p < 0.05 for NDG.

Discussion

In the present study, we examined the differences in respiratory efficiency and exercise tolerance between non-diabetic and diabetic patients in the absence of chronic heart failure. At best, our results confirmed our initial hypothesis that DG presented lower exercise tolerance than NDG. On the other hand, respiratory function was preserved in T2DM patients in absence of chronic heart failure, despite reduced OUES and circulatory power than NDG.

Lower peak VO₂ and exercise tolerance for DG demonstrated a common feature related to T2DM that is poor cardiorespiratory fitness and exercise tolerance. The values for VO₂peak and anaerobic threshold correspond closely to patients with T2DM described in other studies. Thus, even in an asymptomatic disease with few years, it seems that the cardiorespiratory system already has a gradual deterioration that can be detected by a simple CPX test. Evidences seem to indicate that diabetes and elevated blood glucose constitute important comorbidities with impact on lung function, that result in restrictive alterations. Studies have demonstrated that rest pulmonary function tests are significantly decreased in subjects with T2DM in comparison to healthy control groups and this might be the result of direct exposure to elevated blood glucose. In this context, Davis et al. proposed that reduced lung volume and airflow limitation might be considered as chronic complications of T2DM. Abnormal glycosylation led an increase on connective tissue in lungs, therefore, another possible mechanism to diabetic patient show a poor pulmonary diagnosis is related with insulin resistance, that may decrease respiratory muscle strength and affect all respiration process. These alterations have an impact on exercise capacity and quality of life across functional stages of airflow limitation. Interestingly, our study
shows that even in T2DM patients in absence of chronic heart failure and preserved rest pulmonary function, CPX was able to detected reductions in exercise capacity and respiratory efficiency. Although DG has consulted a physician before the study, we couldn’t exclude the possibility of undiagnosed coronary or peripheral artery disease that may compromise exercise tolerance. Further studies should consider coronary or peripheral artery disease impact on exercise tolerance in T2DM.

CPX is a specialized subtype of exercise testing that provides a more accurate and objective measure of cardiorespiratory fitness. Once largely under the domain of the physiologist or specialized center, CPX currently has the potential to be used for a wide spectrum of clinical applications, which includes ventilatory efficiency and risk stratification for respiratory complications. In this research, besides the traditional poor cardiorespiratory fitness and exercise intolerance, CPX was able to detect reduced OUES and circulatory power in T2DM patients in absence of chronic heart failure when compared to NDG.

Thus, we recommend that CPX for T2DM patients provided not only information about cardiorespiratory fitness and exercise intolerance but also respiratory efficiency parameters, such as $\dot{V}V_{E}/\dot{V}V_{CO}_2$ slope, OUES, circulatory and ventilatory power. Peak $\dot{V}V_{O}_2$ and $\dot{V}V_{E}/\dot{V}V_{CO}_2$ slope are currently the most studied CPX variables and both demonstrate strong independent prognosis value of cardiovascular risk, however, these parameters are applied to patients with heart failure. When CPX is performed with T2DM patients in absence of chronic heart failure, even with reduced peak $\dot{V}V_{O}_2$ compared to non-diabetic subjects, cardiorespiratory fitness can be misled with a sedentary lifestyle. Furthermore, an abnormally high $\dot{V}V_{E}/\dot{V}V_{CO}_2$ slope is associated with a poor prognosis when low peak $\dot{V}V_{O}_2$ values (< 18 mL·(kg·min)$^{-1}$) were reported. As we presented in this study, $\dot{V}V_{E}/\dot{V}V_{CO}_2$ slope for T2DM patients was far from cutoff points to predict high risk of cardiac events and presented no difference from non-diabetic subjects. Thus, it’s interesting to analyze other respiratory parameters to evaluate and detect possible differences that originates from T2DM and not from sedentary lifestyle.

In attempt to avoid supra cited effects on maximal capacity or exercise intolerance, OUES was developed to analyze respiratory efficiency and is mainly applied in cardiac patients. In this research, T2DM presented lower OUES than non-diabetics and also demonstrated a lower increase in $\dot{V}V_{O}_2$ in response to a given $\dot{V}V_{E}$. In other words, oxygen extraction at the lungs and its distribution through the body is impaired in T2DM. Based on physiological explanation of OUES, it seems that even in T2DM in absence of chronic heart failure perfusion to the lungs are affected – increase in physiologic pulmonary dead space and carbon dioxide production is increased – metabolic acidosis. Indeed, high BLC at rest observed in DG can be indicative of metabolic acidosis observed in T2DM patients. Finally, circulatory power, considered another predictor of cardiovascular outcome in patients with chronic heart failure, was analyzed in the present study. Our results indicate that peak circulatory power was able to detect differences between DG and NDG, even in absence of chronic heart failure. T2DM in absence of chronic heart failure had a reduced circulatory power when compared to ND, indicating an increased cardiovascular risk. Cohen-Solal et al. state that peak circulatory power should not be viewed as only a perfect surrogate of cardiac power, but as a new global index that incorporates, besides $\Delta \dot{V}V_{O}_2$ difference, heart rate, stroke volume and blood pressure responses, all parameters whose prognostic value has been demonstrated.

Unfortunately, both peak circulatory power and OUES are widely studied only in chronic heart failure patients. We are unaware of any previous investigation, which has compared peak circulatory power or OUES on diabetic and non-diabetic population. Thus, peak circulatory power and OUES measures presented in this study doesn’t permit to establish the degree of ventilatory or cardiorespiratory impairment neither a prognosis prediction. This research was only able to detect differences in CPX variables between a sample of T2DM and non-diabetic individuals. Since the difference were identified in a small sample and can be physiologically explained, we recommend a large-scale study of these variables in T2DM in absence of chronic heart failure. It is possible that large-scale researches can identify cutoff points for OUES and circulatory power for cardiovascular prognosis.

Conclusions

In conclusion, T2DM without chronic heart failure presented exercise intolerance and lower cardiorespiratory fitness demonstrated by lower workload and $\dot{V}V_{O}_2$ at ventilatory threshold and lower peak workload and peak $\dot{V}V_{O}_2$. 

R. bras. Ci. e Mov 2018;26(2):34-42.
Peak circulatory power and OUES were also reduced in T2DM, showing impairment on lung and heart function in T2DM absent of chronic heart failure. It can be assessed non-invasively through a maximum CPX test. Future studies should explore OUES and peak circulatory power in T2DM patients in absence of chronic heart failure.

Acknowledgements

We thank CAPES for founding our research and the Sao Carlos Federal University exercise physiology laboratory, especially Professor Sergio Perez, PhD and NAFES, especially Professor Eduardo Kokubun, PhD.

References

Avaliação da função cardiorrespiratória em diabéticos
R. bras. Ci. e Mov 2018;26(2):34-42.


41. Davis WA, Knuiman M, Kendall P, Grange V, Davis TM, Fremantle Diabetes S. Glycemic exposure is associated


