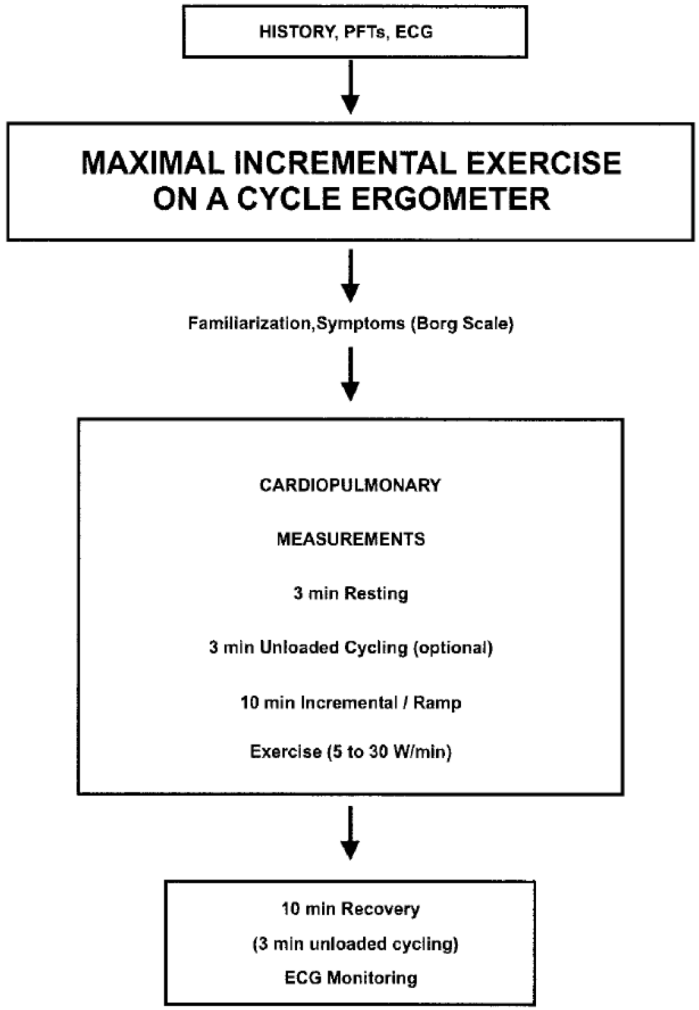
# Kardio-pulmonales exercise testing (CPET)




Messungen während des Tests:

| Measurements | Noninvasive | Invasive (ABGs) |
|---|---|---|
| External work | WR | |
| Metabolic gas exchange | $\dot{V}O_2$, $\dot{V}CO_2$, RER, AT | Lactate |
| Cardiovascular | HR, ECG, BP, $O_2$ pulse | |
| Ventilatory | $\dot{V}E$, VT, fR | |
| Pulmonary gas exchange | $Sp_{O_2}$, $\dot{V}E/\dot{V}CO_2$, $\dot{V}E/\dot{V}O_2$, $PET_{O_2}$, $PET_{CO_2}$ | $Pa_{O_2}$, $Sa_{O_2}$, $P(A–a)O_2$, VD/VT |
| Acid–base | | pH, $Pa_{CO_2}$, standard $HCO_3^-$ |
| Symptoms | Dyspnea, fatigue, chest pain | |

Stop des Tests, falls eines der Folgenden auftritt:

Chest pain suggestive of ischemia
Ischemic ECG changes
Complex ectopy
Second or third degree heart block
Fall in systolic pressure > 20 mm Hg from the highest value during the test
Hypertension (> 250 mm Hg systolic; > 120 mm Hg diastolic)
Severe desaturation: $Sp_{O_2} \leq 80\%$ when accompanied by symptoms and signs of severe hypoxemia
Sudden pallor
Loss of coordination
Mental confusion
Dizziness or faintness
Signs of respiratory failure

# Kardio-respiratorisches exercise testing (CPET)

Kriterien für einen 'normalen' Test, d.h. für eine maximale Ausbelastung der Person

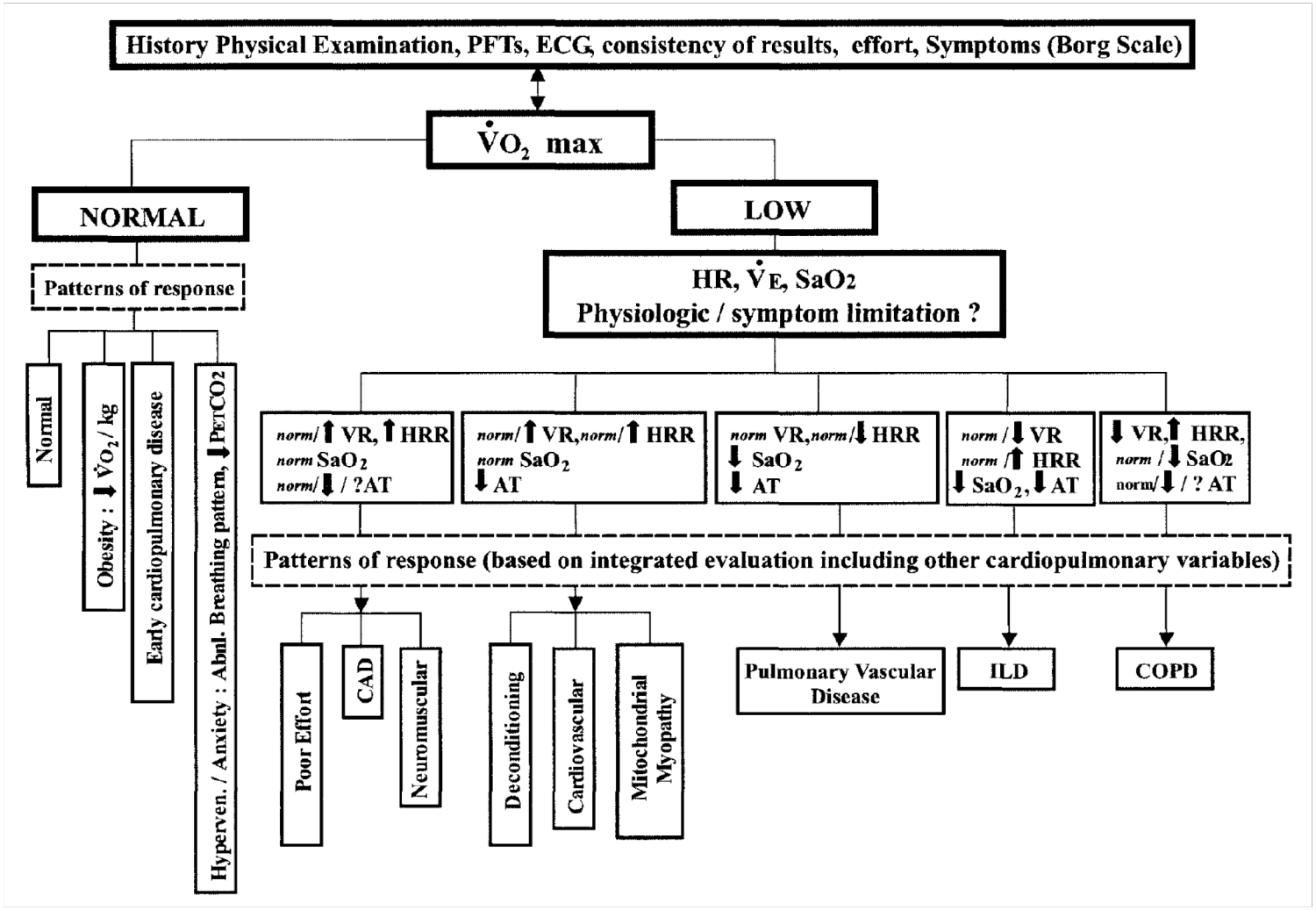
| Variables | Criteria of Normality |
|---|---|
| $\dot{V}O_2$max or $\dot{V}O_2$peak | > 84% predicted |
| Anaerobic threshold | > 40% $\dot{V}O_2$max predicted; wide range of normal (40–80%) |
| Heart rate (HR) | HRmax > 90% age predicted |
| Heart rate reserve (HRR) | HRR < 15 beats/min |
| Blood pressure | < 220/90 |
| $O_2$ pulse ($\dot{V}O_2$/HR) | > 80% |
| Ventilatory reserve (VR) | MVV − $\dot{V}E$max: > 11 L or $\dot{V}E$max/MVV × 100: < 85%. Wide normal range: 72 ± 15% |
| Respiratory frequency ($f_R$) | < 60 breaths/min |
| $\dot{V}E/\dot{V}CO_2$ (at AT) | < 34 |
| $V_D/V_T$ | < 0.28; < 0.30 for age > 40 years |
| $Pa_{O_2}$ | > 80 mm Hg |
| $P(A–a)O_2$ | < 35 mm Hg |

# Kardio-respiratorisches exercise testing (CPET)

Übliche Veränderungen bei folgenden kardio-respiratorischen Erkrankungen

| Measurement | Heart Failure | COPD | ILD | Pulmonary Vascular Disease | Obesity | Deconditioned |
|---|---|---|---|---|---|---|
| $\dot{V}O_2$max or $\dot{V}O_2$peak | Decreased | Decreased | Decreased | Decreased | Decreased for actual, normal for ideal weight | Decreased |
| Anaerobic threshold | Decreased | Normal/decreased/ indeterminate | Normal or decreased | Decreased | Normal | Normal or decreased |
| Peak HR | Variable, usually normal in mild | Decreased, normal in mild | Decreased | Normal/slightly decreased | Normal/slightly decreased | Normal/slightly decreased |
| $O_2$ pulse | Decreased | Normal or decreased | Normal or decreased | Decreased | Normal | Decreased |
| $(\dot{V}E/MVV) \times 100$ | Normal or decreased | Increased | Normal or increased | Normal | Normal or increased | Normal |
| $\dot{V}E/\dot{V}CO_2$ (at AT) | Increased | Increased | Increased | Increased | Normal | Normal |
| $VD/VT$ | Increased | Increased | Increased | Increased | Normal | Normal |
| $Pa_{O_2}$ | Normal | Variable | Decreased | Decreased | Normal/may increase | Normal |
| $P(A–a)O_2$ | Usually normal | Variable, usually increased | Increased | Increased | May decrease | Normal |

# Strategie zur Auswertung eines CPET



# Beispiel 1 – normaler CPET

62-jähriger, weisser Mann

- hat das Leben lang geraucht
- seit 6 Monaten mehr Dyspnoe bei Aktivität

62-year-old male; white; height, 175 cm; weight, 84 kg; ideal weight, 78 kg
Clinical Dx: Exertional dyspnea
Medications: None
Reason for testing: Shortness of breath on exertion

**Resting Pulmonary Function Tests**

| Variable | Actual | % Pred | Variable | Actual | % Pred |
|---|---|---|---|---|---|
| FVC, L | 4.50 | 99 | TLC, L | 6.52 | 103 |
| $FEV_1$, L | 3.10 | 88 | RV, L | 2.54 | 109 |
| $FEV_1$/FVC, % | 69 | | $D_{LCO}$, ml/min per mm Hg | 26.3 | 91 |
| MVV, L/min | 124 | | | | |

normal

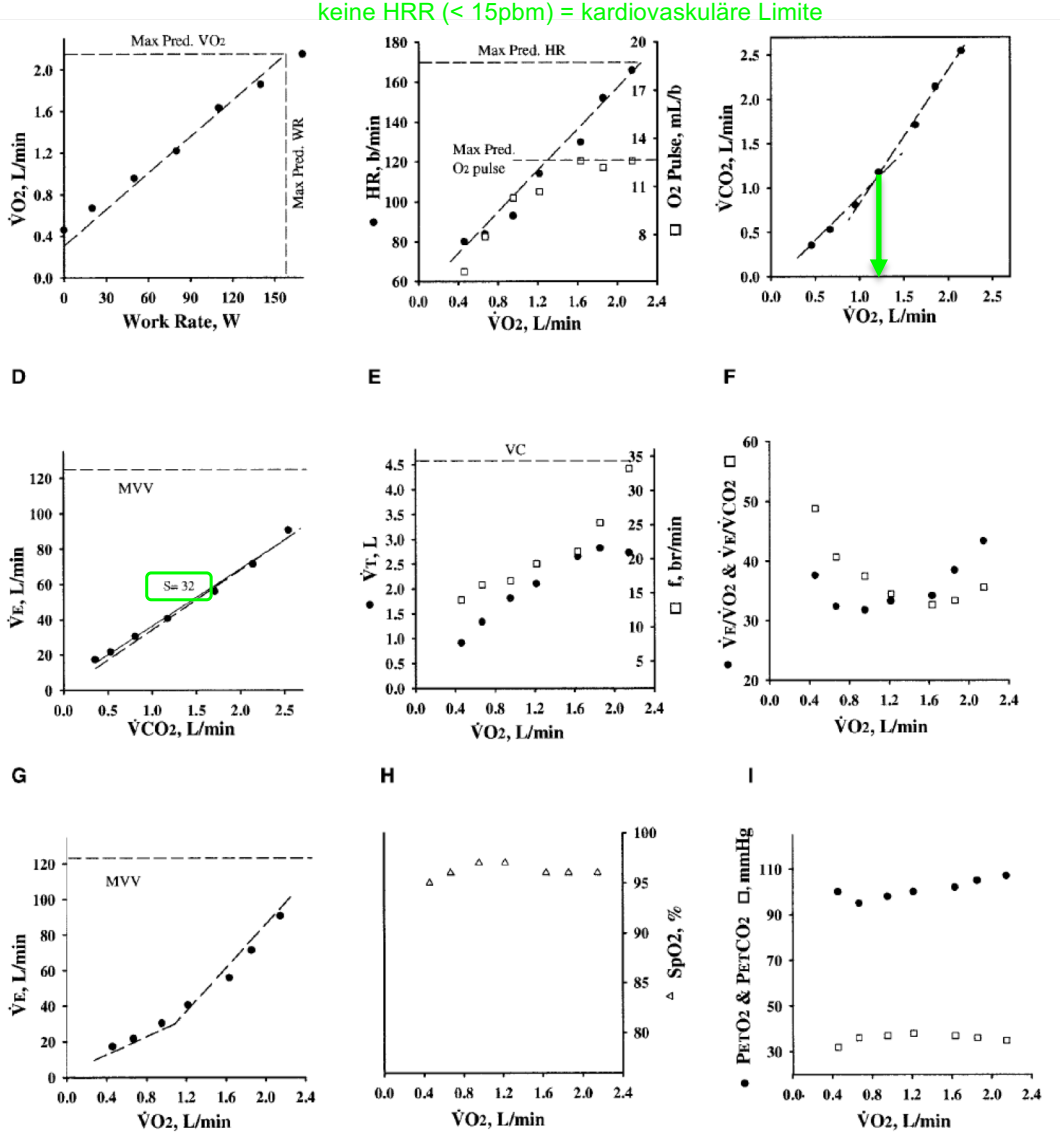
**Cardiopulmonary Exercise Test**

Protocol: Maximal, symptom limited, incremental cycle ergometry, 30 W/min
$P_B$, 722 mm Hg; $P_{I_{O_2}}$, 142 mm Hg

| Variable | Peak | % Pred | Variable | Rest | Peak |
|---|---|---|---|---|---|
| Work rate, W | 170 | 109 | $Sa_{O_2}$, % | | |
| $\dot{V}_{O_2}$, L/min | 2.1 | 98 | $Sp_{O_2}$, % | 95 | 96 |
| $\dot{V}_{O_2}$, ml/kg per min | 25.6 | 91 | $Pa_{O_2}$, mm Hg | | |
| AT, L/min | 1.05 | N (> 0.86) | $Pa_{CO_2}$, mm Hg | | |
| $\Delta\dot{V}_{O_2}/\Delta$WR, ml/min/W | 10.3 | N (> 8.6) | pH | | |
| HR, beats/min | 166 | 98 | $HCO_3^-$, mEq/L | | |
| $O_2$ pulse, ml/beat | 12.6 | 100 | $P(A–a)O_2$, mm Hg | | |
| BP, mm Hg | 176/90 | | $V_D/V_T$ | | |
| $\dot{V}_E$, L/min | 90.7 | 73 | Lactate, mEq/L | | |
| $f_R$, breaths/min | 33 | N | | | |
| $\dot{V}_E/\dot{V}_{CO_2}$, at AT | 34 | N | | | |
| RER | 1.21 | | **Stop:** Dyspnea, 7/10; leg fatigue, 5/10 | | |

maximaler Effort

keine HRR (< 15pbm) = kardiovaskuläre Limite



# Beispiel 2 - Kardiomyopathie

## 49-jährige, weisse Frau

- schwere, linksventrikuläre Hypokinesie
- PAH, Blutdruck 68/32 mmHg (Mittel 45 mmHg)
- 45 py und 3-4 Gläser Alkohol (bis vor 5 Monaten )
- CPET wegen Evaluation für Transplantation (EF < 25%)

49-year-old female; white; height, 163 cm; weight, 52.6 kg; ideal weight, 63.1 kg
Clinical Dx: Severe dilated cardiomyopathy
Medications: Carvedilol, lisinopril, Lasix, KCl, Coumadin, Paxil, cerivastatin, Premarin, Pepcid
Reason for testing: Evaluation for heart transplantation.

**Resting Pulmonary Function Tests**

| Variable | Actual | % Pred | Variable | Actual | % Pred |
|---|---|---|---|---|---|
| FVC, L | 3.44 | 96 | TLC, L | 5.08 | 100 |
| $FEV_1$, L | 2.39 | 85 | RV, L | 1.61 | 102 |
| $FEV_1$/FVC, % | 70 | | $D_{LCO}$, ml/min per mm Hg | 10.5 | 46 |
| MVV, L/min | 129 | 128 | | | |

normal

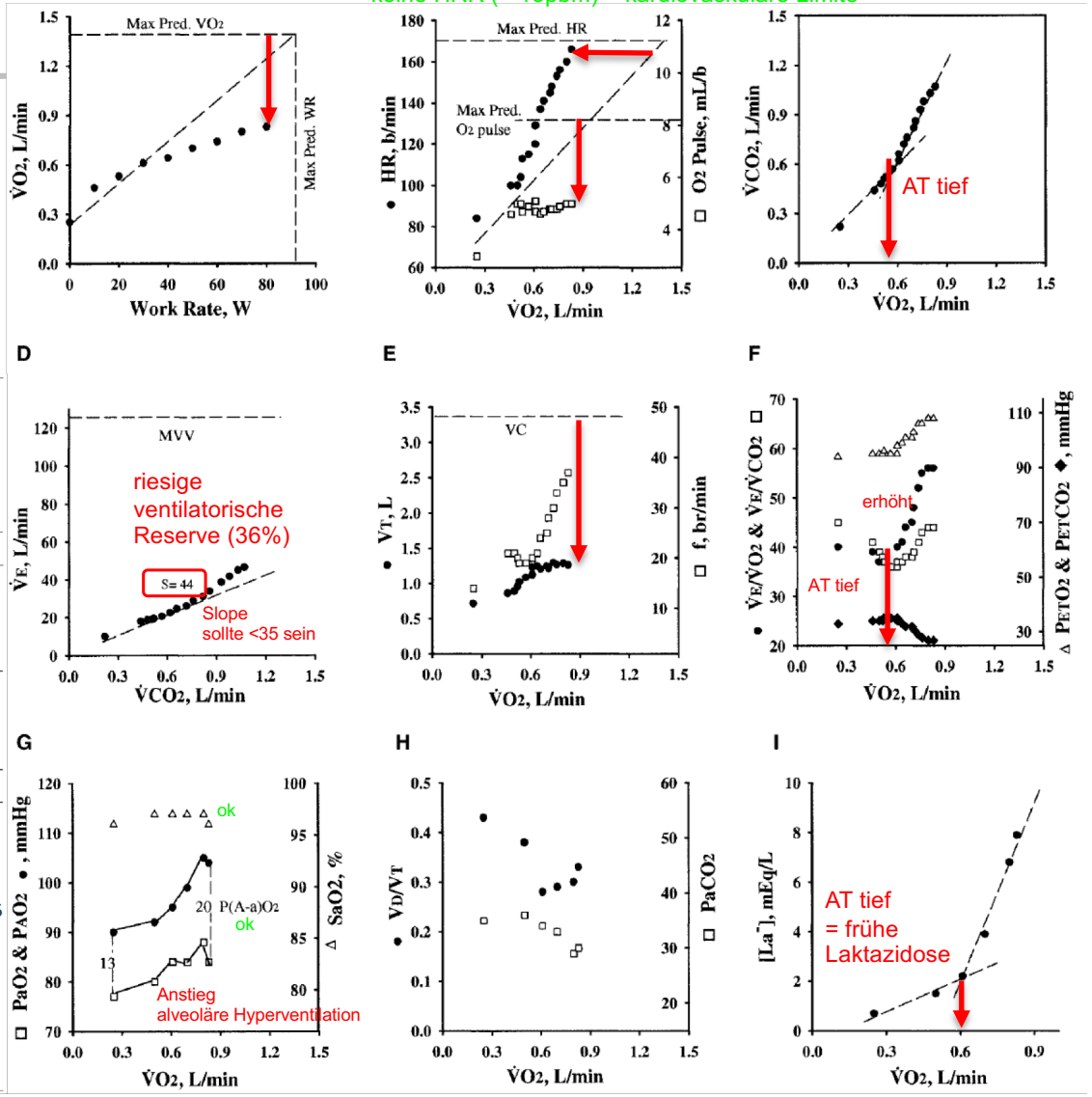
**Cardiopulmonary Exercise Test**

Protocol: Maximal, symptom limited, incremental cycle ergometry, 20 W/min
$P_B$, 656 mm Hg; $P_{I_{O_2}}$, 128 mm Hg

≤ 50% wäre schlechte Überlebensprognose

| Variable | Peak | % Pred | Variable | Rest | Peak |
|---|---|---|---|---|---|
| Work rate, W | 80 | 88 | $Sa_{O_2}$, % | 96 | 95 |
| $\dot{V}_{O_2}$, L/min | 0.83 | 60 | $Sp_{O_2}$, % | 95 | 85 |
| $\dot{V}_{O_2}$, ml/kg per min | 15.8 | 60 | $Pa_{O_2}$, mm Hg | 77 | 84 |
| AT, L/min | 0.60 | L (> 0.76) | $Pa_{CO_2}$, mm Hg | 35 | 30 |
| $\Delta\dot{V}_{O_2}/\Delta WR$, ml/min/W | 5.1 | L (> 8.6) | pH | 7.451 | 7.346 |
| HR, beats/min | 166 | 94 | $HCO_3^-$, mEq/L | 24 | 17 |
| $O_2$ pulse, ml/beat | 5.0 | 64 | $P(A-a)O_2$, mm Hg | 13 | 20 |
| BP, mm Hg | 174/87 | | $V_D/V_T$ | 0.43 | 0.33 |
| $\dot{V}_E$, L/min | 47 | 36 | Lactate, mEq/L | 0.7 | 7.9 |
| $f_R$, breaths/min | 37 | N | | | |
| $\dot{V}_E/\dot{V}_{CO_2}$, at AT | 37 | H | | | |
| RER | 1.28 | | **Stop:** Dyspnea, 3/10; leg fatigue, 4–5/10 | | |

keine HRR (< 15pbm) = kardiovaskuläre Limite






maximaler Effort

Bild einer kardiovaskulären Erkrankung, $O_2$-Delivery Limitation; Deconditioning und Muskeldysfunktion nicht ausgeschlossen

# Beispiel 3 - COPD

## 66-jähriger, weisser Mann

- gut kontrollierte Hypertonie und Reflux
- > 50py, stoppte Rauchen vor 12 Jahren
- CPET, da innerhalb des letzten Jahres verstärkt Dyspnoe bei Aktivität

66 year-old male; white; height, 175 cm; weight, 61 kg; ideal weight,: 77.5 kg
Clinical Dx: Severe COPD
Medications: Ipratroprium bromide, budesonide, salmeterol, as-needed Proventil, Tagamet
Reason for testing: Evaluation of functional capacity and worsening of dyspnea

**Resting Pulmonary Function Tests**

| Variable | Actual | % Pred | Variable | Actual | % Pred |
|---|---|---|---|---|---|
| FVC, L | 2.44 | 55 | TLC, L | 9.45 | 139 |
| $FEV_1$, L | 0.88 | 25 | RV, L | 7.01 | 303 |
| $FEV_1$/FVC, % | 36 | | $D_{LCO}$, ml/min per mm Hg | 16.5 | 51 |
| MVV, L/min | 38 | | | | |

**Cardiopulmonary Exercise Test**

Protocol: Maximal, symptom limited, incremental cycle ergometry, 10 W/min
$P_B$, 656 mm Hg, $P_{IO_2}$, 128 mm Hg

| Variable | Peak | % Pred | Variable | Rest | Peak |
|---|---|---|---|---|---|
| Work rate, W | 70 | 65 | $Sa_{O_2}$, % | 92 | 83 |
| $\dot{V}O_2$, L/min | 1.06 | 66 | $Sp_{O_2}$, % | 90 | 85 |
| $\dot{V}O_2$, ml/kg per min | 17.4 | 66 | $Pa_{O_2}$, mm Hg | 65 | 55 |
| AT, L/min | 0.75 | N (> 0.64) | $Pa_{CO_2}$, mm Hg | 38 | 46 |
| $\Delta\dot{V}O_2/\Delta WR$, ml/min/W | 9.3 | N (> 8.6) | pH | 7.413 | 7.279 |
| HR, beats/min | 141 | 84 | $HCO_3^-$, mEq/L | 24 | 21 |
| $O_2$ pulse, ml/beat | 7.5 | 79 | $P(A-a)O_2$, mm Hg | 20 | 27 |
| BP, mm Hg | 166/72 | | $V_D/V_T$ | 0.45 | 0.42 |
| $\dot{V}_E$, L/min | 46 | 121 | Lactate, mEq/L | 1.4 | 6.9 |
| $f_R$, breaths/min | 36 | N | | | |
| $\dot{V}_E/\dot{V}CO_2$, at AT | 44 | H | | | |
| RER | 1.03 | | **Stop:** Dyspnea, 10/10 | | |

HRR, ca. 27 bpm

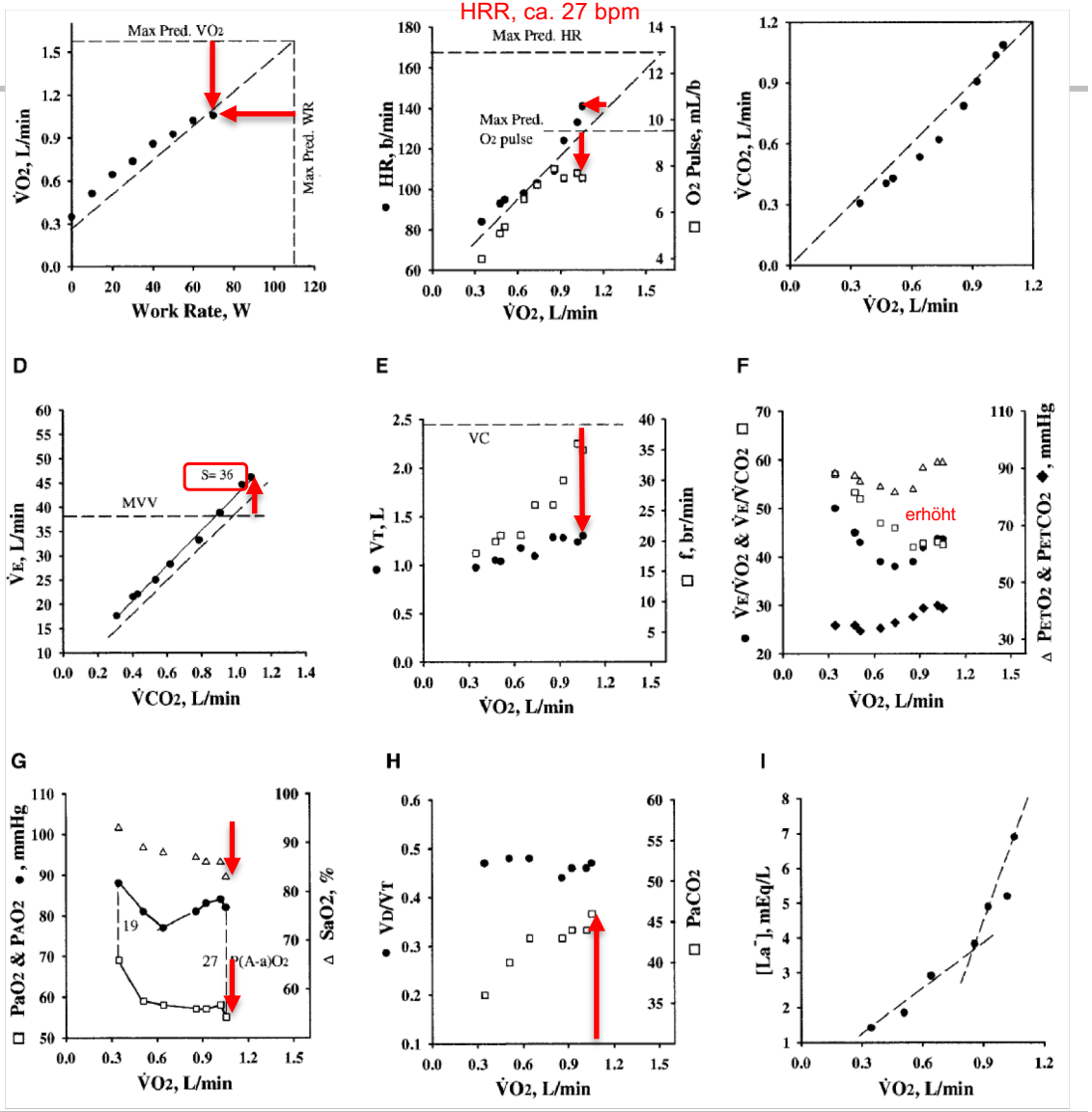





Bild einer ventilatorischen Limitierung, evtl. mit Deconditioning

# Beispiel 4 – interstitielle Lungenfibrose

## 72-jähriger, weisser Mann

- lebenslanger Nichtraucher, keine Medi, normales EKG
- innerhalb des letzten Jahres verstärkt Dyspnoe bei Aktivität
- Rx: interstitielle Fibrose
- CPET, zur Bestimmung der Entsättigung vor Start mit Cortison

72 year-old male; white; height, 170 cm; weight, 80 kg; ideal weight, 74 kg
Clinical Dx: Idiopathic pulmonary fibrosis
Medications: None
Reason for testing: IPF: assessment of exercise tolerance, evaluate desaturation

**Resting Pulmonary Function Tests**

| Variable | Actual | % Pred | Variable | Actual | % Pred |
|---|---|---|---|---|---|
| FVC, L | 2.34 | 60 | TLC, L | 3.78 | 66 |
| $FEV_1$, L | 1.70 | 65 | RV, L | 1.60 | 67 |
| $FEV_1$/FVC, % | 72 | | $D_{LCO}$, ml/min per mm Hg | 12.2 | 43 |
| MVV, L/min | 61 | | | | |

**Cardiopulmonary Exercise Test**

Protocol: Maximal, symptom limited, incremental cycle ergometry, 15 W/min
$P_B$, 722 mm Hg; $P_{I_{O_2}}$, 142 mm Hg

| Variable | Peak | % Pred | Variable | Rest | Peak |
|---|---|---|---|---|---|
| Work rate, W | 95 | 64 | $Sa_{O_2}$, % | 94 | 80 |
| $\dot{V}_{O_2}$, L/min | 1.19 | 67 | $Pa_{O_2}$, mm Hg | 72 | 49 |
| $\dot{V}_{O_2}$, ml/kg per min | 14.9 | 62 | $Pa_{CO_2}$, mm Hg | 42 | 42 |
| AT, L/min | 0.80 | (> 0.70) | pH | 7.39 | 7.31 |
| HR, beats/min | 132 | 81 | $P(A–a)O_2$, mm Hg | 24 | 47 |
| $O_2$ pulse, ml/beat | 9.0 | 83 | $V_D/V_T$ | 0.40 | 0.40 |
| BP, mm Hg | 172/86 | | | | |
| $\dot{V}_E$, L/min | 57 | 93 | | | |
| $f_R$, breaths/min | 42 | N | | | |
| $\dot{V}_E/\dot{V}_{CO_2}$, at AT | 49 | H | | | |
| RER | 1.04 | | **Stop:** Dyspnea, 6/10; leg fatigue, 5/10 | | |

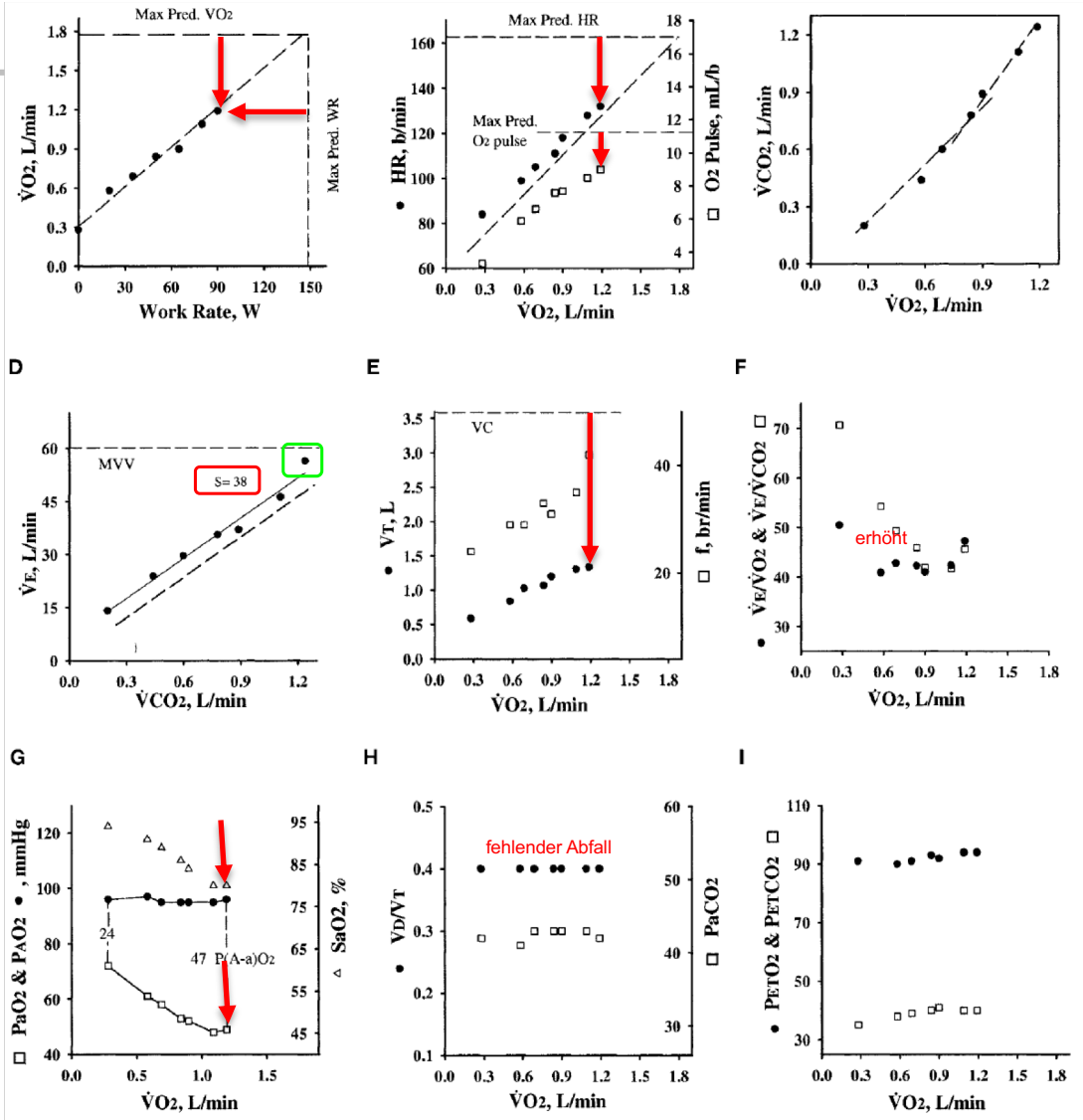





Bild einer ventilatorischen Limitierung mit Deconditioning