Declaration of conflict of interest

• E. Skobel and C. Knackstedt have received consultant honoraria from Philips.
• P. Schauerte, A. Martinez, B. Scheibe-Schmidt no conflict interest.
Evaluation of a newly designed shirt-based ECG- and breathing sensor for training during cardiac rehabilitation for coronary artery disease

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Session: Novel approaches to exercise training
Funding

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Background

• Despite the fact that multiple advantages of cardiac rehabilitation are well known there is lack of home-based supervised training.
• Thus, participation in phase III cardiac rehabilitation is low and new devices are needed to improve supervised training for cardiac patients.
GEx (Guided-Exercise)-System

- Closed-loop disease management system for prescription and monitoring of CR in patients with coronary artery disease.
- Designed to record ECG, heart rate (HR), respiratory rate (RR) and exercise related signals.
- Specific sensors are held in place by means of a dedicated shirt during exercise.
- Data is uploaded to a professional application via a patient station in order to monitor ECG data by a training specialist.
Components of the portable station

- Shirt
- PDA
- ECG-(image)-sensor with charging device
Original data of image sensor displayed on PC

- **ECG**
- **Accelerometer and Position**
- **Breathing signal**
- **Breathing frequency**

**HR**

**Style of exercise (position)**

- **Standing**
Heart rate displayed on PDA by image sensor

Target heart rate

Actually achieved heart rate transferred by image sensor
Aim of the study

• Comparison of standard spiroergometry (CPX) and GEx-Sensor for validation of the accuracy of the sensor during phase-II cardiac rehabilitation based on ECG and breathing-frequency during exercise.

• CPX was performed at the beginning and at the end of rehabilitation first with ecg-data on PC and at the end ecg-data displayed on PDA by the image sensor.
Methods

• CPX bicycle exercise test (Viasys-Jäger) with simultaneous GeX measurement

• 50 patients (multiple conditions):
  CABG N=26,  
  Myocardial infarction n=22,  
  Valve replacement n=9,  
  Pacing (multiple devices) n=4,  
  ICD n=2

• Measurements:
  12-lead-ecg, HR,  
  VO2, VCO2, BF, VE

• Exercise protocol:
  2 Min. rest, 2 Min. warmup,  
  Incremental exercise 20 watts/min up to exhaustion or maximum heart rate
Patients characteristics

<table>
<thead>
<tr>
<th></th>
<th>N=50, 7 female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>70 ± 9</td>
</tr>
<tr>
<td>BMI</td>
<td>26 ± 3</td>
</tr>
<tr>
<td>Time after intervention (d)</td>
<td>35 ± 13</td>
</tr>
<tr>
<td>EF (%)</td>
<td>58 ± 11</td>
</tr>
<tr>
<td>Maximum watts</td>
<td>90 ± 22</td>
</tr>
<tr>
<td>VO2 peak (ml/min/kg)</td>
<td>13.4 ± 4</td>
</tr>
</tbody>
</table>
### Medications (multiple denominations)

<table>
<thead>
<tr>
<th>Medication</th>
<th>Number of patients (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ß-blockers</td>
<td>45 (90 %)</td>
</tr>
<tr>
<td>Aspirine</td>
<td>46 (92 %)</td>
</tr>
<tr>
<td>Clopidogrel</td>
<td>23 (46 %)</td>
</tr>
<tr>
<td>Warfarine</td>
<td>10 (20 %)</td>
</tr>
<tr>
<td>Amiodarone</td>
<td>9 (18 %)</td>
</tr>
<tr>
<td>Aldactone</td>
<td>8 (16 %)</td>
</tr>
<tr>
<td>Diuretics</td>
<td>30 (60 %)</td>
</tr>
<tr>
<td>Ace-inhibitors</td>
<td>26 (52 %)</td>
</tr>
<tr>
<td>Calcium-channel blockers</td>
<td>22 (44 %)</td>
</tr>
<tr>
<td>AT-II-blockers</td>
<td>9 (18 %)</td>
</tr>
</tbody>
</table>
MEASUREMENT OF SIMULTANEOUS GEX-SENSOR AND CPX MONITORING

EXAMPLE OF 2 PATIENTS
Patient 1

- Male, 68 years
  - Coronary artery disease
  - CABG 25.1.11
- EF 59 %
- Diabetes mellitus type 2

- Medication: ß-Blocker, ACE-inhibitor, Calcium-Antagonist, ASS, Torasemid, Statine, Insuline
Example 1: rest data GEx-system

ECG
Heart Rate

Breathing frequency
Example 1: Rest (simultaneous CPX)

Simultaneously recorded ECG and HR

ECG

HR

VO2 / VCO2

EQO2 / EQCO2
Example 1: Exercise (Gex-system)

ECG
Heart Rate

Breathing frequency
Example 1: Exercise (simultaneous CPX)
Patient 2

- Male, 66 years
- Coronary artery disease
- CABG and Aortic-Valve-Replacement (Perimount magna 25 mm) 03-01-11
- AV-Block III
  - DDD-Pacer 10-01-11 Biotronik Entovis DR-T DDD-CLS 60-130
  - EF 45 %
- Medication: ASS, Valsartan, Bisoprolol, HCT, Aldactone, Furosemide, Statine
Example 2: rest (pacing, VES), GEx-system

ECG
Heart Rate

Pacing

Breathing frequency
Example 2: rest (simultaneously recorded CPX)

Pacing
Comparison of heart rate (HR) and breathing frequency (BF) during exercise and recovery in CPX

N=50, X ± SEM
Correlation of HR monitored using GEx-device and CPX

$y = 0.9873x + 1.1894$

$R^2 = 0.9738$

N=50
Correlation of breathing-frequency monitored using GEx-device and CPX

\[ y = 0.8246x + 4.6426 \]

\[ R^2 = 0.7462 \]

N=50
Correlation HR CPX versus PDA

\[ y = 1.0199x - 1.3048 \]
\[ R^2 = 0.9701 \]

N=50
GEx-Database

Evaluation of training information and ECG transferred to a central database via internet
Impressions of the Professional station

Heart rate and blood pressure measurement

HR before training

Blood pressure
Heart rate measurement during training

Performed training sessions

HR during training

Overview over training session
Impressions during training - ECG

Data of training session - ECG
Conclusion

• The newly GEx-sensor is able:
  – to accurately report data on heart rate, ECG and respiratory rate during exercise
  – to monitor exercise in CAD-patients

• A good correlation was found compared to standardized CPX.

• The sensor combined with a dedicated T-shirt is easy to handle and to wear.

• The whole system seems feasible for monitoring of home-based CR.
Thank you for your attention
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