INTERNET-BASED CYCLE ERGOMETER SUPPORTING A PERSONAL FITTING PROCESS FOR THE ELDERLY

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Abstract-The Internet-based cycle ergometer system has been studied to establish a new type of service regarding the personal fitting process for the elderly. In the personal fitting process, the workload variation can be updated based on the balance between the objective indices (heart rate and muscular fatigue-related indices) and the subjective index. The results showed that the balance was effective to determine the appropriate timings and levels of workload change for individual elderly persons. The Internet-based cycle ergometer system was useful to proceed with the sequential personal fitting process.

Keywords - cycle ergometer, personal fitting, heart rate, muscle activity, ratings of perceived exertion
Purpose

Social Background
- progression of aged society
- high motivation for health

However
- risk for overuse
- physical work capacity
  - degeneration of functions
  - large individual differences

Health Promotion by Exercise
“Wellness”

IT system
to support Exercise for Wellness

Internet-based Healthcare System for serving Personally Fitted Workload
Internet-based Supporting System (i-SS) for Monitoring

1. Internet-camera for monitoring
   - measurement
   - analysis
   - storage
   - database

2. Internet-camera for monitoring
   - measurement
   - analysis
   - database

3. Internet-camera for monitoring
   - measurement
   - analysis
   - database

4. Internet-camera for monitoring
   - measurement
   - analysis
   - database

- network capacity
- security
- analysis
- Internet-hard disk
i-SS for Home-based Health Promotion

Exercise at any time and at any location

Browsing by Java made programs

Internet-based Cycle Ergometer Supporting a Personal Fitting Process for the Elderly

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Workload Control for Cycle Ergometer

Control by Objective Indices

Recursive Workload Control

\[ WL_{n+1} = WL_n - \delta \cdot \Delta WL \]

Heart Rate (HR)

Surface EMG(SEMG)

- amplitude info
- frequency-related info.

Fuzzy control
- Fuzzy Rules
- Membership Functions

SEMG, HR

Estimation of Total fatigue index \( \delta \)

Controlling Workload

\( WL_n \): workload at \( n \)-th frame

\( \Delta WL \): incremental step of workload

\( \delta \): fatigue index
Objective Indices

Surface Myoelectric Signals

Amplitude index
\[ ARV(m) = \frac{1}{N} \sum_{k=m}^{m+N-1} |emg(k)| \]

Frequency index
\[ MPF(m) = \frac{\sum_{f=f_L}^{f_H} f \cdot P(m, f)}{\sum_{f=f_L}^{f_H} P(m, f)} \]

Muscular fatigue index
\[ \gamma_{ARV-MPF} \]

Heart Rate
\[ HR \]

\( m \) : frame number
\( N \) : number of samples in a frame
\( emg \) : samples of ME signals

\( P(m, f) \) : power spectrum of ME signal at \( m \)-th frame
\( f_H \) : high-frequency limit for estimation
\( f_L \) : low-frequency limit for estimation
Heart Rate

\[ \gamma_{ARV-MPF} \]

Progressively increasing workload
Types in HR-$γ_{ARV-MPF}$ Scatter Graph

- **Type A**
  - $γ_{ARV-MPF}$ decreases as a function of time

- **Type A'**
  - quite similar to Type A, but $γ_{ARV-MPF}$ shows negative value from the beginning of exercise

- **Type B**
  - $γ_{ARV-MPF}$ remains negative value from the beginning.

- **Type C**
  - $γ_{ARV-MPF}$ shows positive value as a function of time

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Changes in HR-$\gamma_{\text{ARV-MPF}}$ Scatter Graph

(a) first set  
April, 2000

(b) fourth set  
November, 2000

seven months

progressively increasing workload

type-A

subject TH (a 70-year-old man)
Periodically Customization of Workload

**Design**

- **Progressively Increasing Workload**
  - Workload
  - Time
  - Measured interval

**Redesign**

- Check the time-series of parameters
- Controlled Workload around AT
  - Determined by RPE

**Fuzzy membership functions**
- Design the Fuzzy Rules based on the AT

**Fuzzy rules**
- Controlled Workload

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Workload Control Process

Design of Control Parameters
- Fuzzy Rules
- Membership Functions

PIW : Progressively Increasing Workload
CW : Controlled Workload

Key points
- classification
- segmentation

Key points
- Personal fitting

From now on

PIW
CW1
CW2
CW3
PIW

Up to now

Updating Control Parameters

trial
Objective / Subjective Representation of Fatigue

**Objective Data**

- **myoelectric signals**
- **electrocardiogram**

**Subjective Representation**

RPE (Ratings of Perceived Exertion) by Borg (Med. Sci. Sports Exerc. 1973)

<table>
<thead>
<tr>
<th>RPE-Scale</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Very, very light</td>
</tr>
<tr>
<td>8</td>
<td>Very light</td>
</tr>
<tr>
<td>9</td>
<td>Fairly light</td>
</tr>
<tr>
<td>10</td>
<td>Somewhat light</td>
</tr>
<tr>
<td>11</td>
<td>Hard</td>
</tr>
<tr>
<td>12</td>
<td>Very hard</td>
</tr>
<tr>
<td>13</td>
<td>Very, very hard</td>
</tr>
</tbody>
</table>

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Indices for Personal Fitting

Comparison

\[ \varepsilon(n) = RPE(n) - \hat{RPE}(n) \]

- Subjective indices
- Objective indices
- Estimation error

Estimation of RPE

\[ \hat{RPE}(n) = \text{ANN} \]

\[ \text{ANN} \]

\[ \gamma_{\text{ARV-MPF}}(n) \]

\[ \Delta WL(n) \]

\[ WL(n) \]

\[ HR(n) \]
Estimation of RPE by ANN

Selection of suitable ANN

Numbers of cells at each layer were 4 at the input, 4 - 20 at the middle, and 1 at the output (the total number of ANNs checked was 25).

\[ \varepsilon(n) = RPE(n) - \hat{RPE}(n) \]

minimum squared error

suitable ANN for personal fitted workload control
Experimental Conditions

- **Subjects**
  18 senior subjects (63.5±7.5 years old)
  __from September 2000 to March 2001 every 2 months__
  8 senior subjects (69.3±*.* years old)
  __from November 2001 to December 2001 every 2 weeks__

- **Myoelectric Signals**
  muscles: right leg vastus lateralis
  gain: 60dB
  frequency band width: 5.3Hz - 1.2kHz
  4-bar active array electrode

- **Heart Rate**
  LED-photo transistor

- **Metabolism**
  lactate in blood every minute
  respiration gas exchange every minute

- **Subjective Index**
  ratings of perceived exertion (RPE)
Workload Design for Personal Fitting

Temporary increasing workload

How to determine:
- level
- timing

Protocol for Exercise

Conventional WL control

\[ WL_{\text{min}} = 70\%WL_{AT} \]
\[ WL_{\text{max}} = 130\%WL_{AT} \]

Little bit hard exercise and recognition of workload changes

AT: Anaerobic Threshold

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Subject KY
2001-Nov-11

• phase 3: 100%WL_AT ε increasing

• phase 5: 110%WL_AT ε decreasing

Type-A, 73-years-old man

WL_AT=97 W, WL_LT=120 W
Timing of Temporary Increasing Workload

![Graphs showing HR, WL, and RPE over time with annotations]

**Insufficient example for PF**

**Sufficient example for PF**

Subject KY

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ARV-MPF Scatter Graph

- HR around AT
- No severer muscular fatigue

(a) Lighter than PIW
(b) Relatively light for muscles, but hard for respiration
(c) Appropriate exercise, comfortable

HR-γ_{ARV-MPF} Scatter Graph
Conclusions

Personally Fitted Process

1. Evaluation of basic data under progressively increasing workload.

2. Continuously changing the intensity and timing of temporary increasing workloads.

3. Comparison between subjective index (RPE) and objective indices.
   - small error between RPE and estimated RPE.
   - RPE greater than 13 and no progression of muscular fatigue.

Wellness Bike for Home-Based Exercise