Extracting Stationary Segments from Non-Stationary Synthetic and Cardiac Signals

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INTRODUCTION

Global Prevalence of Diabetes

Estimates for the year 2000 and projections for 2030

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OBJECTIVE — The goal of this study was to estimate the prevalence of diabetes and the number of people of all ages with diabetes for years 2000 and 2030.

RESEARCH DESIGN AND METHODS — Data on diabetes prevalence by age and sex from a limited number of countries were extrapolated to all 191 World Health Organization member states and applied to United Nations’ population estimates for 2000 and 2030. Urban and rural populations were considered separately for developing countries.

RESULTS — The prevalence of diabetes for all age-groups worldwide was estimated to be 2.8% in 2000 and 4.4% in 2030. The total number of people with diabetes is projected to increase from 171 million in 2000 to 366 million in 2030. The prevalence of diabetes is higher in men than women, but there are more women with diabetes than men. The urban population in developing countries is projected to double between 2000 and 2030. The most important demographic change to diabetes prevalence across the world appears to be the increase in the proportion of people >65 years of age.

CONCLUSIONS — These findings indicate that the “diabetes epidemic” will continue even if levels of obesity remain constant. Given the increasing prevalence of obesity, it is likely that these findings provide an underestimate of future diabetes prevalence.

Diabetes Care 27:1047–1053, 2004

The number of people with diabetes is increasing due to population peared, further epidemiological data have become available for several countries in 1990 (2) using newer data and different methods for estimating age-specific prevalence. As before, the estimates are based on demographic changes alone with the conservative assumption that other risk factors such as obesity and physical activity remain constant (in developed countries) or are accounted for by urbanization (in less developed countries). The current estimates include all age-groups, and age-specific data are presented (online appendix [available at http://care.diabetesjournals.org]) to allow comparison with previous estimates that were for adults only (2). As most data sources do not distinguish between type 1 and type 2 diabetes in adults, it is not possible to present data separately for subtypes of diabetes.

RESEARCH DESIGN AND METHODS — Diabetes prevalence data for adults (≥20 years of age) were derived from studies meeting the following criteria: a defined, population-based sample and diagnosis of diabetes based on optimal WHO criteria (a venous plasma glucose concentration of >11.1 mmol/l 2 h after a 75-g glucose tolerance test).
Cardiovascular Autonomic Neuropathy (CAN) is one of the most ignored irreversible complications of diabetes.

A clinical indicator of CAN is the decrease in heart rate variability (HRV).

Diabetics are intolerant to exercise, therefore to properly assess their physical condition they should undergo a cardiac stress test (CST).
The **RR interval** time series acquired during **CST** shows a **non-stationary** behavior that may produces **erroneous** interpretations of the **HRV**
The heuristic segmentation methodology used was the one proposed by Bernaola-Galván et al.

\[
t = \left| \frac{\mu_1 - \mu_2}{S_D} \right|,
\]

\[
S_D = \left( \frac{(N_1 - 1)s_1^2 + (N_2 - 1)s_2^2}{N_1 + N_2 - 2} \right)^{1/2} \left( \frac{1}{N_1} + \frac{1}{N_2} \right)^{1/2}
\]

\[
P_{(t_{max})} \approx \left\{ 1 - I_{v/(v+t_{max}^2)}x(\delta v, \delta) \right\}^\gamma
\]

The Heuristic method was tested on:

- **Synthetic signals**
  - Known location of stationary segments
  - Validation of accuracy
- **RR real signals**
  - Two populations
  - Searching for differences in number and length of stationary segments

**Goal:** find differences in length and number of stationary segments
**Synthetic signals**
- 250 synthetic signals x 10000 samples/signal
- Five different groups:
  - SNR = 1dB
  - SNR = 5dB
  - SNR = 10dB
  - SNR = 15dB
  - SNR = 20dB
- 50 signals per group
**Real Database**: 26 subjects divided in two groups,

- **Group 1 (diabetic)**: 18 subjects with CAN (men, age=57±10 years old, weight=73±15 kg), presenting diabetes mellitus type II

- **Group 2 (control)**: 8 subjects (men, age 50±06 years old, weight = 81±20 kg), asymptomatic, with no known pathology and ECG at rest without alterations.

- ECG acquisition protocol

**ECG acquisition protocol**

1. **Supine**: 3 min.
2. **Hyperventilation, seating**: 1 min.
3. **Stress test, Modif. Bruce Protocol**
**Methods and Results**

### Databases

- Validation: Synthetic Signals
- Stationary Segments: Real Signals

### Real Database:

**HRV: Diabetic subject**

**HRV: Control subject**
Performance evaluation was made through sensitivity and positive predictive value

**TP:** The beginning or end of the stationary segment falls within a window (length = 80 samples) centered at the given annotation.

**FP:** The beginning or end of the stationary segment does not match with any annotation within the window.

**FN** or miss detection: The beginning or end of the stationary segment is not detected within the window.
# Methods and Results

## SNR Sensitivity (%) and Positive Predictive Value (%)

### The beginning

<table>
<thead>
<tr>
<th>SNR</th>
<th>Sensitivity (%)</th>
<th>Positive predictive value (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 dB</td>
<td>54.5</td>
<td>57.4</td>
</tr>
<tr>
<td>5 dB</td>
<td>60.8</td>
<td>60.4</td>
</tr>
<tr>
<td>10 dB</td>
<td>76.2</td>
<td>67.6</td>
</tr>
<tr>
<td>15 dB</td>
<td>89.4</td>
<td>71.4</td>
</tr>
<tr>
<td>20 dB</td>
<td>95.7</td>
<td>75.3</td>
</tr>
</tbody>
</table>

### The end

<table>
<thead>
<tr>
<th>SNR</th>
<th>Sensitivity (%)</th>
<th>Positive predictive value (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 dB</td>
<td>50.5</td>
<td>52.1</td>
</tr>
<tr>
<td>5 dB</td>
<td>59.5</td>
<td>58.8</td>
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<tr>
<td>10 dB</td>
<td>74.6</td>
<td>65.2</td>
</tr>
<tr>
<td>15 dB</td>
<td>88.0</td>
<td>70.2</td>
</tr>
<tr>
<td>20 dB</td>
<td>94.3</td>
<td>74.1</td>
</tr>
</tbody>
</table>
Methods and Results

Statistical differences (p < 0.05) were between groups except for groups SNR1dB vs. SNR5dB.

Box plots for beginning and ending delays

Statistical differences (p < 0.01) were found between all groups.
✓ Detection of the **beginning** seems to be easier than the detection of the **end**

✓ From non-stationary => stationary, cut point **after** the point where the mean value

✓ From stationary => non-stationary, cut point **before** the point where the mean changes

✓ Results obtained on synthetic signals are quite satisfactory.
Neuropatía Autonómica Cardiaca

Methods and Results

Databases

Validation:
Synthetic Signals

Real Signals

RR Series

Segmentation algorithm.

stationary segments per group

Mann-Whitney U test
**Methods and Results**

### Databases

### Validation: Synthetic Signals

### Stationary Segments Real Signals

<table>
<thead>
<tr>
<th>Group</th>
<th>Duration stationary segments (s)</th>
<th>Number stationary segments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diabetics</td>
<td>50.27±24.95</td>
<td>5.50±2.55</td>
</tr>
<tr>
<td>Control</td>
<td>44.02±14.73</td>
<td>6.10±3.00</td>
</tr>
</tbody>
</table>
• We have divided synthetic and cardiac non-stationary time series into several stationary segments

• Future work: assessment of HRV for diabetic CAN and healthy subjects using time-domain and frequency-methods on the stationary sequences extracted from the stress test
AGRADECIMIENTOS
QUESTIONES