A smartphone application for preventing exercise-induced glycemic imbalances in type 1 diabetic patients

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a healthy lifestyle has to include physical exercise, even for patients with type 1 diabetes mellitus
- exercise improves insulin sensitivity,
- may help to maintain a better metabolic control,
- protective effects against several cardiovascular risk factors
- can increase psychological well being.

However, exercise-associated glycaemic imbalances may be dangerous and difficult to control
- Each patient has to discover, by trial and error, his/her own strategy and several attempts are usually required

Fear of hypoglycaemia remains the strongest barrier to physical exercise, discouraging to practice sports
Background/2: ECRES

- **Exercise Carbohydrate Requirement Estimating Software**
  - algorithm to estimate the amount of extra carbohydrates required by diabetic patients in order to exercise under safe glycaemia levels.
  - Patented by two Authors of this paper (MPF, AA)
  - tested on 27 patients who performed for three times 1-hr constant intensity walk.
    - in about 70% of the trials, independent of the time of day, the algorithm provided a satisfactory estimate of the carbohydrates needed by patients to complete the exercise with a safe glucose level.

**Glycaemia depends on diet, therapy, training habits, specific activity**
- consumption forecast
- realtime estimate
Aims

• Since the number of smartphone applications aimed at diabetic patients is growing quickly:
  1. estimate the likely interest for an exercise-supporting application that implements the above mentioned algorithm.
  2. propose an implementation of the ECRES algorithm aimed at smartphones
  3. preliminarily evaluate it from the accuracy point of view versus the original implementation
  4. preliminarily evaluate it from the user point of view
Materials and methods/1

- review of literature on mobile applications supporting self-management of diabetes
  - with attention to physical exercise support

- implementation of the ECRES algorithm:
  - calculation of carbohydrate intake needed to carry out a scheduled physical activity basing on expected intensity and duration,
  - and real time calculation of glucose consumption during physical activity based on heart rate, thanks to a heart rate monitor connected to the smartphone.
  - Alerts when hypoglycaemia is being forecasted
  - Remote storage of data

Preliminary usability and interest evaluation on T1DM patients enrolled among students

- Execution of tasks defined by scenarios
Results/1

• physical exercise feature: available in 34% of applications in online stores, up to 55% if considering only applications retrieved in literature.
  • If we assume that applications from literature may precede market trends,
  • then physical exercise related features may have a higher prevalence in future.

• A further confirmation: user ratings.
  • app global rating is 3.54, vs. 3.89 for apps with physical exercise related features.

• no application is specific for T1DM,
• no support for self-management of glucose level during exercises.
Results/2

- **Android** platform has been chosen vs. IOs because of Bluetooth capabilities

  - and **Polar WearLink®+ Bluetooth** heart rate monitor

- The developed application consists of:

  - a **mobile side**, that occasionally connects with a server through a web service-based protocol
  
  - A **server side** storing diets, therapies, and activities

- All the designed features have been implemented on the mobile side,

  - while the server side is still in a preliminary version.
### Screenshots

**Beyond diabetes**

Ok, you're ready to start the exercise. If you haven't done it yet, take an amount of 7.0 grams of carbohydrates. These are required to you to perform 30 minutes of jogging safety, with an average heart rate of 86 bpm with a glucose level of 110.

- **Use heart rate transmitter (if available)**
- **Use GPS (if available)**

Start exercise!

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**Beyond diabetes**

**Connected to Polar IWL**

Elapsed time **00:26**

<table>
<thead>
<tr>
<th>Current heart rate</th>
<th>88</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current average heart rate</td>
<td>91</td>
</tr>
<tr>
<td>Expected carbohydrates consumption</td>
<td>8</td>
</tr>
</tbody>
</table>

**Carbohydrates consumed during exercise** 7

- Current Speed 11 km/h
- Average speed 12 km/h
- Altitude 144 m
- Covered distance 5600 m

Pay attention, you could be near a hypoglycemic level!

Stop exercise

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**Beyond diabetes**

**Connected to Polar IWL**

Elapsed time **00:30**

<table>
<thead>
<tr>
<th>Current heart rate</th>
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<tbody>
<tr>
<td>Current average heart rate</td>
<td>91</td>
</tr>
<tr>
<td>Expected carbohydrates consumption</td>
<td>8</td>
</tr>
</tbody>
</table>

**Carbohydrates consumed during exercise** 8

- Current Speed 10 km/h
- Average speed 12 km/h
- Altitude 142 m
- Covered distance 6000 m

Please stop! You're in a really dangerous situation!!!

Stop exercise
The mobile algorithm implementation, forecasting version, has been tested against the original one, by loading the same therapy and diet data sets used for the initial validation.

The same kind of activities have been then simulated on the mobile application.

On 27 patient data sets, results have been equivalent.
Results/4: preliminary usability evaluation

• email invitation to all University students

• 14 subjects (8M 6F), mostly young, 4 owning smartphone, 10 doing sports

• Some correlation between weak glycaemic control capabilities (measured by HbA1c) and satisfaction
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- email invitation to all University students
- 14 subjects (8M 6F), mostly young, 4 owning smartphone, 10 doing sports
- Some correlation between weak glycaemic control capabilities (measured by HbA1c) and satisfaction
Discussion

- For **some activities** the proposed app seems to provide a good decisional support, which may meet T1DM needs and expectances.

- Further developments:
  - Implementation of **heart rate approximations** calculated depending on previous patient exercises, when relevant (e.g. in running or cycling, recorded by GPS)
    - More personalisation, reduced dependence from heart rate belt
  - Interface to Bluetooth-based glucometers, in order to simplify even their readings.
Thanks

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