Automatic Detection of Exercise in People with Type 1 Diabetes Using an Unscented Kalman Filter

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BACKGROUND

- Evidence suggests regular physical activity improves cardiovascular health, lipid profiles, psychological wellbeing and, possible glycaemic control in patients with type 1 diabetes (T1D).[1]
- However, control of glucose levels during exercise is extremely challenging, as:
  1. insulin levels cannot change rapidly in response to exercise[2] and
  2. exercise results in a transient change in the glucose/insulin dynamics' parameters, leading to increased effectiveness of insulin[3].
- During aerobic exercise there is a risk of exercise-induced hypoglycemia.[4]
- Exercise detection within a reasonable time may be useful to a glucose controller in aid of mitigating the hypoglycaemia incurred by aerobic exercise.

METHODOLOGY

This is a proof-of-concept study to assess the ability to detect exercise without the use of physical activity sensors (e.g. accelerometers, heart rate monitors).

1. Data was obtained from 6 subjects undergoing 24-hour closed-loop artificial pancreas trials with aerobic exercise (30 min at 70% VO_2max) 2 hours after a lunchtime meal (50g).
2. An Unscented Kalman filter (UKF) algorithm was used to estimate the states $\hat{x}(k)$ of an extended glucose-insulin minimal model[5-8] and an additional disturbance parameter using only the information provided by a continuous glucose monitor (CGM) and the amount insulin delivered via an insulin pump.
3. Two thresholds were implemented on the difference of the disturbance parameter for exercise detection: a first threshold to indicate the possibility of an abnormal event set at $-2\,mg/dl/min$; and a second area-under-the-curve (AUC) threshold of 9 mg/dl to indicated exercise.

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RESULTS

Results obtained were satisfactory with an average detection time of 26.67 ± 30.4 minutes, accuracy of 95.96 ± 2.5%, specificity of 95.85 ± 2.5% and sensitivity of 100.0 ± 0%.

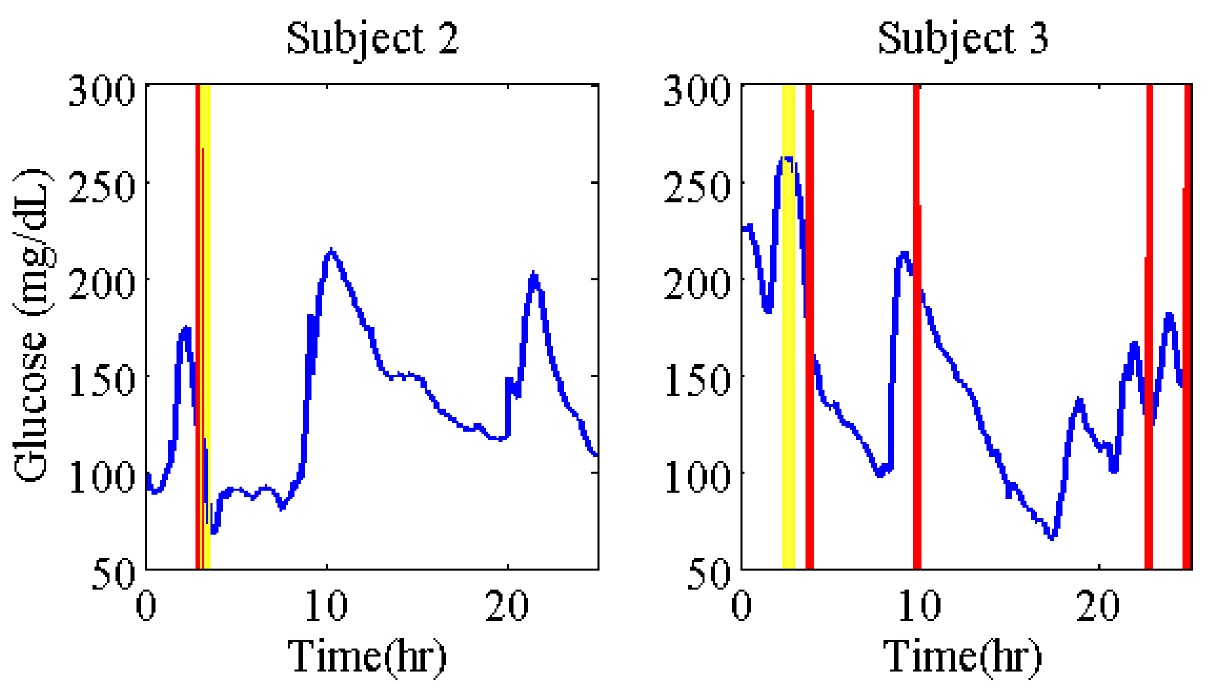

Figure 1. The best (left) and worst (right) clinical data results of the disturbance threshold exercise detection technique. The yellow shaded area indicates exercise and the red lines show when exercise is detected.

Table 1. Performance metrics of the exercise detection algorithm.

Subject	Accuracy	Specificity	Sensitivity	Detection Time (min)
1	94.54	94.39	100.00	45.00
2	100.00	100.00	100.00	-5.00
3	92.98	92.81	100.00	50.00
4	97.59	97.53	100.00	10.00
5	95.33	95.22	100.00	65.00
6	95.29	95.17	100.00	-5.00
Mean	**95.96 ± 2.5**	**95.85 ± 2.5**	**100.00 ± 0**	**26.67 ± 30.4**

CONCLUSION

- A validated *in silico* environment inclusive of exercise is required before *in silico* testing with this algorithm in conjunction with control strategies can be done to validate this method.
- We believe that this algorithm will aid in the development of safe closed-loop systems without built-in physical activity sensors and in the event of a failure in systems that do have physical activity sensors.

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