

1 **Exercising with an automated insulin delivery system: Qualitative insight into the hopes**  
2 **and expectations of people with type 1 diabetes**

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21 **Key Points:**

- 22 • Perceived impact of using automated insulin delivery systems for people with Type 1  
23 Diabetes and their families was explored in four sites (US, UK)
- 24 • Hopes, expectations and impact on sports and exercise was a key theme
- 25 • Automated insulin delivery systems could improve confidence to exercise for people  
26 with Type 1 Diabetes and their families.

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28 **Keywords:** Automated insulin delivery system; Type 1 Diabetes; Qualitative research;  
29 Exercise; Physical activity

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31

1 **Abstract**

2 For people with type 1 diabetes (T1D), regular exercise can be highly beneficial. Although  
3 exercise has been shown to improve quality of life and health for people living with T1D,  
4 there are common barriers. To examine such issues, we explored the perceived impact that  
5 automated insulin delivery systems could have on the person with T1D and their families.  
6 One common theme found was hopes, expectations and impact on sports and exercise. Four  
7 sites (3-United States, 1-UK) were involved in this study. 284 participants (children (8-11  
8 years), adolescents (12-18 years), parents/caretakers of children and adolescents with T1D;  
9 adults with T1D and their significant others/partners) were recruited across all sites. Between  
10 May and December 2015, focus groups and structured interviews were conducted and  
11 analysed using content analysis. Three themes found related to the benefits of automated  
12 insulin delivery systems: (a) more freedom and spontaneity in the individual's ability to  
13 exercise; (b) relief from worry of hypoglycaemia as a result of exercise; (c) removing the  
14 "guesswork" of adjusting insulin for exercise. Two further themes emerged relating to  
15 potential concerns with regard to safely exercising while wearing automated insulin delivery  
16 systems. Further research is encouraged into providing accurate algorithms and increase  
17 confidence for those using automated insulin delivery systems and their loved ones.

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## 1 **Introduction**

2 Regular exercise for people with type 1 diabetes (T1D) has been shown to benefit insulin  
3 sensitivity, reduce cardiovascular risk factors, improve quality of life, and reduce mortality  
4 for people with T1D.<sup>1</sup> However, there are also common barriers to exercise for people with  
5 T1D. The main barriers linked to T1D and exercise were fear of hypoglycaemia and lack of  
6 knowledge about managing diabetes and its complications around exercise<sup>1,2</sup> Using an insulin  
7 pump provides flexibility in controlling the timing and amount of insulin delivered,  
8 addressing some of the barriers to exercise.<sup>3</sup> The addition of a continuous glucose monitor  
9 (CGM) offers greater control over blood glucose levels and may help make exercise more  
10 feasible.<sup>4</sup> Training is required to ensure effective use of these technologies, addressing bolus  
11 doses pre and post exercise<sup>3</sup> and managing post exercise hyperglycaemia.<sup>3</sup>

12 The automated insulin delivery systems include an insulin pump and CGM device  
13 along with an algorithm embedded in either the insulin pump or a separate handheld device  
14 that coordinates insulin delivery by the pump based upon the CGM results. In safety and  
15 efficacy trials, automated insulin delivery systems have shown to decrease hypoglycaemia<sup>5,6</sup>.  
16 However, no known research outside of clinical trials exists which focuses on the  
17 expectations of such systems. To address this gap, we explored the perceived impact that  
18 automated insulin delivery systems would have on the person with T1D and their families.  
19 One common theme found was hopes, expectations and impact on sports and exercise.

## 20 **Participants and Methods**

21 Four sites (Stanford University School of Medicine, California; Bournemouth University,  
22 UK; the Joslin Diabetes Center, Boston; and the Lurie Children's Hospital, Chicago) were  
23 involved in this study. Ethical approval was granted from each institution's Institutional  
24 Research Board prior to recruitment. 284 participants were recruited across all sites through  
25 flyers posted in clinics and hospitals, social media, as well as current infrastructures (e.g.  
26 support groups).<sup>7,8</sup> (see Table 1). Participants with and without knowledge and/or experience  
27 of automatic insulin delivery systems were recruited and no specific manufacturer details of  
28 current or previous pumps and/or CGM were provided. Participants included: children (aged  
29 8-11 years) and adolescents (aged 12-18 years) with T1D; parents/caretakers of children and  
30 adolescents with T1D; adults with T1D and their significant others/partners. (Insert Table 1  
31 here)

1           Between May and December 2015, focus groups and structured interviews were  
2 conducted. Subsets of participants using pumps, CGM, and automated insulin delivery  
3 systems were included, but separated according to method of treatment. For example, those  
4 who had already experienced participating in a clinical trial of an AID system would be  
5 interviewed separately to those who had yet to have any experience with an AID system.  
6 Each site used a team of experienced and qualified focus group/interview facilitators who  
7 worked from the same structured topic guide and explored in depth key issues around  
8 expectations of the automated insulin delivery system, hopes, anxieties, reasons for uptake,  
9 perceived benefits/barriers, impact on daily function, possible reasons for discontinuation and  
10 potential barriers to optimal engagement. An explanation of the automated insulin delivery  
11 system was not provided to enable the participants to discuss what they knew of the  
12 technology and their hopes and expectations of this new technology. Following transcription  
13 of the audio files, the data was analysed using thematic analysis<sup>8</sup>. The full method (e.g., full  
14 inclusion criteria, sample questions, analysis) of this study has been published<sup>7, 8</sup>.

## 15 **Results**

16 Three overriding themes were commonly discussed related to benefits of automated insulin  
17 delivery systems that included: (a) more freedom and spontaneity in the individual's ability to  
18 exercise; (b) relief from worry of hypoglycaemia as a result of exercise, and, (c) removing the  
19 "guesswork" of adjusting insulin for exercise. There were also two further themes that  
20 emerged related to potential concerns with regard to safely exercising while wearing  
21 automated insulin delivery systems. First, we will present findings regarding the potential  
22 benefits, followed by participant concerns.

### 23 *Freedom to exercise*

24 With regards to exercise, one of the most commonly discussed beliefs about automated  
25 insulin delivery systems was the possible freedom it would provide. One aspect of this  
26 freedom was being able to partake in exercise without constantly checking blood sugar  
27 levels:

28           It'd be nice on long runs, not to have to worry about getting low blood sugar. That  
29 would be nice. As it is, I always carry sugar with me, but sometimes, when I'm on a  
30 long run, I just don't feel like eating sugar (Adult, Focus group).

31           It would be useful during exercise. Because if it was still making my blood sugar have  
32 better control, it would stop me from getting low during exercise and then spiking

1 afterwards. I think it would be very useful if you do a lot of sport (Adolescent, Focus  
2 group).

3 Experiencing hypoglycemia during intense or vigorous exercise is a common barrier to  
4 exercise. The ability to be able to consistently train without a worry of experiencing  
5 hypoglycemia was a perceived benefit:

6 If we're just talking about something that's say similar to an insulin pump on a CGM,  
7 from a personal perspective, I would be absolutely fine with that if it means that I can  
8 run without becoming hypoglycaemic after only a few miles and it means that I could  
9 smash it through and run any distance that I want to run (Adult, Focus group).

10 Partners of the adult participants with T1D also shared the belief that the freedom to exercise  
11 when they wanted and as hard as they wanted would be a great benefit to their quality of life:

12 Just being able to say we're going to take a walk and we go take a walk. That would  
13 be great (Partner, Focus group).

14 Similarly, children had a notion that automated insulin delivery systems would allow them to  
15 improve sport performance:

16 It's keeping your numbers up during the match, so you don't have to like at half-time,  
17 test and that. You can keep on routines and focus more on the actual game (Child,  
18 Interview).

### 19 ***Relief from worry***

20 The belief that automated insulin delivery systems would provide some relief from constant  
21 worry about the possibilities of going hypoglycaemic and/or hyperglycaemic before, during,  
22 and after exercise was discussed:

23 Yeah,... I coach a junior football team so it would be nice not to have to panic while I  
24 am doing that and I am going to run low and have to run back and grab some more  
25 sweets (Adult, Focus group).

26 The hardest time would probably be when I am doing exercise, because sometimes  
27 when I am doing exercise, I'm quite prone to go very low. And so, that would tell me  
28 if I am going up or going down, and I could just look and think I'm going to do this or  
29 do that and it would just really help (Child, Focus group).

1 Because, personally, sometimes when I do exercise, I go down, and sometimes I go  
2 up... And I don't know how to prepare for it because if I eat food beforehand, and  
3 then I end up going up, I'll go really high. Or if ... I do exercise, I'll go really low. It  
4 would definitely help with that (Adolescent, Interview)

5 Parents and children also highlighted the potential benefit of automated insulin delivery  
6 systems especially during and after exercise for glycaemic control:

7 It's also the 'after exercise' effect that you can never be quite sure what's going to  
8 happen and how long it is going to last for. It [would] be useful for that if you could  
9 go and do the exercise and not have to have all the extra thinking afterwards (Parent,  
10 Focus group)

11 Since you're exercising, your blood sugar goes low. It could probably manage it and  
12 give you glucose at the same time (Child, Focus group)

13 We go to every game and everybody else is dropping their kids off and we're sitting  
14 there just making sure that this – some of the coaches are volunteers so the last thing  
15 you want to do is inconvenience them by “Okay, so if this ever happens, like this red  
16 box right here; if she has this out, she could be low”. And then to her recreational –  
17 the recreational district it is like, I don't know if I feel comfortable trusting – you  
18 know the coaches are great, but it is like, I don't know if they feel comfortable  
19 (Parent, Focus group).

20 The decrease in the constant worry concerning blood sugar levels were reported to aid  
21 frustration that currently can be a deterrent from exercise.

22 It can be really frustrating to have to eat immediately and so I think if it helped you in  
23 exercise that would be good and actually, I think it would potentially encourage more  
24 people to exercise as well if it took away that risk of hypos and highs (Adult, Focus  
25 group).

26 Partners also discussed the positive impact that this decrease in worry would have in their  
27 partner's enjoyment of exercise.

28 I do like the fact that while she's exercising, (...) the machine would be monitoring  
29 and telling her before she got to that point, “Wait a minute, you just need to back off a  
30 minute,” take a few seconds or a few minutes, and maybe have something to eat if it's  
31 going down too quickly. So I think that would help her, she'd be able to do the

1 exercise and feel a lot more confident that at the end of it her blood sugar is still going  
2 to be okay (Partner, Focus group).

### 3 ***Relief from guesswork***

4 Another potential benefit was the hope that automated insulin delivery systems would be able  
5 to accurately measure blood sugar levels while exercising and adjust accordingly, decreasing  
6 the need to “guess” the correct dose of insulin:

7 It does seem like it would take the human error aspect out of it... So it could  
8 potentially – what I see as a benefit of this being for me is when I go out and ride for  
9 three or four hours then I come home, I don’t have to mess around with these  
10 calculations. Potentially this could help and say okay well I don’t need as much  
11 insulin or my blood sugar is going down and then it would react accordingly (Adult,  
12 Focus group).

13 Again, I can imagine that anything that reduces sort of the guess work of needing to  
14 know where her blood sugar is going to go, and eat appropriately or take the  
15 appropriate amount of insulin. She’d have to eat so much sugar to compensate for her  
16 blood sugar dropping during a workout that it wasn’t worth it. And if the artificial  
17 pancreas [automated insulin delivery systems] could help avoid some of that guess  
18 work, I think it’d be great (Partner, Focus group).

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### 20 **Potential Barriers**

#### 21 ***Doubts about accuracy***

22 Although many participants anticipated a benefit of the system would be to automatically  
23 adjust dosing based on exercise, confusion remained about what the system could offer in  
24 these terms..

25 Sometimes during sports I wouldn’t trust it... Or if I had a low I probably wouldn’t  
26 trust it. For sports, sometimes I’ll get huge spikes, and it’s from adrenaline not from  
27 something else, so I’m afraid it might correct for that, and then just drop me down in  
28 the middle of my hockey game or something and I’d get really sick (Adult, Focus  
29 group).

30 For those who already had experienced using automated insulin delivery systems in clinical  
31 trials, this was shown as one of the results of having used the system.

1 I deliberately didn't do any major walking or cycling on the weekends while I was on  
2 the system because I just didn't want to risk having a bad hypo in the night (Adult,  
3 Focus group).

4 These concerns were also shown as a worry regarding how automated insulin delivery  
5 systems would adjust if they decided not to exercise.

6 No, I think it would actually be more restrictive in some ways. Because right now, I  
7 would have to know, before I would have lunch, for instance, and then I decide 'Oh, I  
8 want to walk after lunch.' Well, I can do something to finagle that, but if I said to it  
9 'About to exercise, and I'm going to have lunch.' And then I decide not to exercise,  
10 then what? (Adult, Focus group).

11 In addition, the terms of 'moderate' versus 'light' or 'vigorous' exercise inserted into the  
12 system feared it could potentially cause a problem.

13 [Respondent 4]: What is moderate exercise and what is light exercise?

14 [Respondent 5]: And how would you know what you are going to do? Like you could  
15 give yourself insulin for moderate exercise and it turns out you do light exercise  
16 (Adult, Focus group).

17 Well, and I know that [Name] just said, how are we going to define exercise too  
18 because sometimes you will walk seven miles in a day and you don't necessarily think  
19 of it as being exercise; you are just at work and you're busy, so how are we going to  
20 quantify that? Does that only mean we're going to the gym or does that mean being  
21 on your feet at work? I think it is kind of a slippery slope as it is with craving food. I  
22 don't know – or just cleaning your house. You don't always know when you're  
23 'exercising' (Adult, Focus group).

#### 24 ***Physical appearance and comfort***

25 When discussed specific situations where participants would want to disconnect the  
26 automated insulin delivery systems, some participants, mainly teens and children, argued that  
27 they would disconnect it to prevent someone seeing them wearing it during exercise or sport  
28 events.

29 I probably wouldn't want to wear it when I exercise and do sports, but I don't really  
30 have a choice in that. That's the main time of movement where I wouldn't want to  
31 wear it (Child, Focus group).



1 Most participants stated that physical appearance was not a big issue for them. However,  
2 some argued that they would not wear automated insulin delivery systems if the nature of the  
3 exercise or sport prohibited comfortable usage, for example:

4           When I'm doing sports, it would be cool if I'd be able to remove it. Like with my  
5           insulin pump, I could unclip it (Adolescent, Focus group).

## 6 **Discussion**

7 One of the most prominent themes for the participants was the desire to feel they have the  
8 freedom to exercise. The common concern regarding the negative impact and constant worry  
9 while exercising was consistent with previous research.<sup>9,10</sup> However, these results present  
10 participants' hope of lessening this negative impact on their exercise routine through using  
11 automated insulin delivery systems. As inaccuracies of current treatment for exercise has  
12 been a strong deterrent from exercising for those with T1D<sup>1,2,9</sup>, these findings demonstrate  
13 that as systems become more accurate, people with T1D may exercise more regularly. The  
14 sense of freedom was also reported in being able to exercise without restrictions, e.g., not  
15 pausing to eat or drink to prevent hypoglycaemia. This research shows that through the use of  
16 automated insulin delivery systems, more people with T1D may be more confident to  
17 exercise and as a result, feel the benefits of a regular exercise routine.

18           The perceived impact of what using automated insulin delivery systems would be like  
19 was commonly reported as decreased worry with regards to exercising safely. Automated  
20 insulin delivery systems have shown to provide a more accurate level of blood sugar  
21 regulation and decrease instances of hypoglycaemia.<sup>11,12</sup> The participants expressed that with  
22 a constant regulation and ability to automatically adjust blood sugar accordingly to exercise  
23 level, automated insulin delivery systems may decrease worry and fear.

24           The discussions of potential benefits and drawbacks of using automated insulin  
25 delivery systems for exercise have shown it was perceived to be beneficial to not only the  
26 consistency of exercise, but reduce worry of hypo and hyperglycaemic incidents, if  
27 automated insulin delivery systems worked accurately. However, these positives relied on the  
28 ability for the person using automated insulin delivery systems to trust the device, and as  
29 potential uncertainties were evident, this trust might not be arrived at easily. Limitations of  
30 this study were the differences in demographic data collected that limited the ability to  
31 compare across groups based on demographic and behavioural aspects.<sup>7,8</sup>

1 Findings from this study have provided novel first-hand insight into the potential  
2 benefits and barriers to automated insulin delivery systems during exercise. Further research  
3 is encouraged into providing accurate algorithms and increase confidence for those using  
4 automated insulin delivery systems and in turn, their exercise colleagues and loved ones.

## 5 **Conclusion**

6 First-hand insight was shown of the potential benefits and drawbacks of using automated  
7 insulin delivery systems for exercise. Although the insights have been mostly positive and  
8 ones of hope, worries still remain. Trust in the system must play a fundamental role in  
9 onboarding and training associated with automated insulin delivery systems. Automated  
10 insulin delivery systems can potentially lead to an increase in exercise levels for people with  
11 diabetes and, subsequently, improved health status if managed effectively.

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