Automated Insulin Delivery System Use in Canada: Incorporating Perspectives of Both Users and Healthcare Providers

by

Amy E Morrison

A thesis submitted in partial fulfillment of the requirements for the degree of

Master of Science

in

Translational Medicine

Department of Medicine
University of Alberta

Abstract

An Automated Insulin Delivery (AID) system combines an insulin pump and glucose sensor, with utilization of a computerized predictive algorithm, to enable automated adjustment in insulin delivery rate. Do-it-Yourself (DIY) or Open-source AID systems were the first form of this technology available to people with diabetes. These unregulated systems, were developed by people with type 1 diabetes, and are broadly classified into AndroidAPS, OpenAPS and Loop, based upon the technology and algorithm which they incorporate. Individual enthusiasm for developing and using DIY systems has driven their growth and they have been the glucose management system of choice for a small but increasing number of people with diabetes worldwide. Since 2016, forms of commercially approved AID systems have been made available for some people with type 1 diabetes in Canada, and their use associated with improved glycemic and quality of life outcomes.

DIY AID is in contrast to most therapies, which are provided to a patient by their healthcare provider. This role reversal, an absence of the usual methods of safety and efficacy assessment, and not least the unregulated nature of DIY AID, has led to uncertainty for healthcare providers (HCP) in how best to approach DIY AID use. Therefore, we sought to review the benefits of AID and the medico-legal status surrounding DIY AID use in Canada (Chapter 1), identifying an ongoing need for clarification and clinical guidance in this setting. We next performed a scoping review to evaluate the existing evidence base and current benefits with DIY AID use (Chapter 2), this highlighted the majority of evidence available to support DIY AID to be user self-reported data, with seemingly very beneficial outcomes demonstrated. Without the requirement for

licensing, or profit motivation, no randomized control trials (RCT) have been performed for DIY systems.

Our survey used snowball sampling to explore HCP experience and attitudes towards Commercial and DIY AID (Chapter 3). AID system use across Canada was found to be infrequent; 6-24 users of Commercial and 1-5 users DIY AID, in large clinical practices (100-500 patients with type 1 diabetes). Correlation was demonstrated between number of users in their practice and HCP system confidence. Commercial and DIY AID system education for both users and HCP, in addition to medico-legal guidance relating to DIY AID systems, were deemed to be required interventions to improve access to this beneficial technology for people with type 1 diabetes.

Finally, we conducted a study of Loop users (Chapter 4) with a total of 39.2 patient-years user experience, highlighting improvements in glycemic outcomes with Loop (HbA1c and time in range) using a pre-post design. These objective quantitative data were collected alongside semi-structured interviews detailing further the lived experience of Loop use in these individuals. Participants described high levels of treatment satisfaction and low diabetes impact on their quality of life, with no safety concerns with Loop use. Prominent themes constructed from participant viewpoints were explored, these included; empowerment and control, the daily impact of living with diabetes with Loop use, quantification of risk and society's understanding and awareness of Loop.

Together this work provides a comprehensive and wholistic assessment of issues relating to current AID use in Canada considering an assessment of current evidence as well as the perspectives of both Loop users and HCP caring for people with type 1 diabetes in Canada. Users of DIY systems have derived substantial benefits from AID that could benefit many more people with type 1 diabetes. Key gaps identified were in the absence of RCT, need for structured education for users and HCP and the potential value of Canadian guidelines to describe best practice, as well as the challenges of costs and access to technology. It is anticipated that expanded access and use of AID would have benefits for the health and well-being of persons with type 1 diabetes and this thesis highlights some key next steps that could facilitate this.

Preface

This thesis is original work by Amy E Morrison (AM).

Chapter 1 is the basis for a review article manuscript 'Do-It-Yourself and Commercial Automated Insulin Delivery Systems in Type 1 Diabetes – An Uncertain Area for Healthcare Providers' which has been submitted to Canadian Journal of Diabetes. I did the literature review and writing of the manuscript, with editing from co-authors; Peter Senior (PS), Tania Bubela, Kate Farnsworth (KF), Holly Witteman (HW) and Anna Lam (AL).

Chapter 2 is the basis for a pending manuscript 'A Scoping Review of Do-It-Yourself Automated Insulin Delivery (DIY AID) System Use in People with Type 1 Diabetes', authored by AM, Kimberley Chong (KC), PS and AL. I contributed to study design, implementation of search strategy and writing of manuscript, titles were additionally screened by KC, with assistance in decisions surrounding inclusion by AL and manuscript editing by PS.

Chapter 3 is the basis of a pending original research manuscript 'Canadian Healthcare Providers' Attitudes Towards Automated Insulin Delivery Systems', authored by AM, KF, HW, Thomas Crabtree (TC), Emma Wilmot (EW), AL and PS. This details a cross-sectional study which was approved by the University of Alberta Research Ethics Board, study ID Pro00108472. All authors contributed to study design, I performed data collection, analysis and manuscript writing, with manuscript editing by PS.

Chapter 4 is the basis of a pending original research manuscript 'Improved Glycemia and Quality of Life Among Loop Users – Analysis of Real-World Data From a Single Centre', authored by AM, KC, Valerie Lai (VL), PS and AL. This details an observational study which was approved by the University of Alberta Research Ethics Board, Study ID pro00111577. PS and AL contributed to study design, KC and VL data collection, I contributed to study design, data collection, analysis and manuscript writing, with manuscript editing by PS.

Acknowledgements

I would like to express my gratitude to my co-supervisors Dr Anna Lam and Dr Peter Senior for coordinating a Graduate Research Assistant Fellowship position for me at the University of Alberta. In addition to their immense guidance and support throughout the duration of my MSc.

I would like to thank Dr Michael Vallis for agreeing to be on my Supervisory Committee and for his advice and support in the preparation of this thesis.

In addition, I would like to thank the teams that we have collaborated with both in Canada, through Diabetes Action Canada (Kate Farnsworth and Dr Holly Witteman), and in the UK (Dr Emma Wilmot and Dr Thomas Crabtree) at University Hospitals of Derby and Burton.

I am grateful for the financial support enabling me to undertake this work, provided by University of Alberta Department of Medicine Startup funds for Dr Anna Lam.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

ADA	American Diabetes Association
AID	Automated Insulin Delivery
AndroidAPS	Android Artificial Pancreas System
APS	Artificial Pancreas System
ATTD	Advanced Technologies and Treatments for Diabetes
AXIS	Appraisal Tool for Cross-sectional studies
CADTH	Canadian Agency for Drugs and Technology in Health
CDE	Certified Diabetes Educator
CGM	Continuous Glucose Monitor
COM-B	Capability, Opportunity, Motivation, Behavior
CREATE	Community Derived Automated Insulin Delivery Trial
CSII	Continuous Subcutaneous Insulin Infusion
DDG	German Diabetes Association
DDS	Diabetes Distress Scale
DIDS	Diabetes Impact and Device Satisfaction
DIY	Do-It-Yourself
DIYPS	Do-It-Yourself Pancreas System
DKA	Diabetic Ketoacidosis
dQOL	Diabetes related quality of life score
DUK	Diabetes UK
EQ-5D-5L	European Quality of Life Five Dimension Five Level Health Questionnaire
ENTREQ	Enhancing Transparency in Reporting the synthesis of Qualitative research
GMC	General Medical Council
HbA1c	Glycated Hemoglobin
HCP	Healthcare Provider
HFS-II	Hypoglycemia Fear Survey-II
ICR	Insulin to Carbohydrate ratio
IQR	Interquartile range

isCGM	Intermittently scanned Continuous Glucose Monitor
ISF	Insulin Sensitivity Factor
INSPIRE	Insulin Dosing systems: Perceptions Ideas Reflections and Expectations
KEC	Kaye Edmonton Clinic
OPEN	Outcomes of Patient's Evidence with Novel DIYAPS technology
OpenAPS	Open Artificial Pancreas System
Oref0	OpenAPS reference design zero
PRISMA	Preferred Reporting Items for Systematic Review and Meta-Analyses
QOL	Quality of Life
RCT	Randomized Control Trial
RD	Registered Dietician
RN	Registered Nurse
rtCGM	Real time Continuous Glucose Monitor
SaMD	Software as a Medical Device
SAP	Sensor-augmented insulin pump
SGLT2	Sodium-glucose Cotransporter-2
SH	Severe Hypoglycemia
T1D	Type 1 Diabetes
TAR	Time above range
TBR	Time below range
TIR	Time in range
UI	Utility Index
VAS	Visual Analogue Scale

Chapter 1: Do-It-Yourself and Commercial Automated Insulin Delivery Systems in Type 1 Diabetes- An Uncertain Area for Canadian Healthcare Providers

1.1 Introduction

People with type 1 diabetes cannot produce sufficient endogenous insulin and require an external insulin supply to survive, a discovery first demonstrated in humans one hundred years ago by Dr Frederick Banting and medical student Charles Best in Toronto, Canada [1]. Since this time, modes of insulin delivery and diabetes-related technology have greatly expanded. Today, insulin can be delivered to people with type 1 diabetes via subcutaneous injection multiple times daily, or via continuous subcutaneous insulin infusion (CSII) using an insulin pump. An insulin pump comprises an insulin reservoir within a battery-powered pump, which delivers insulin via a subcutaneous cannula (with or without tubing). Current pumps require substantial work by users. Pumps must be programmed, adjusted, and used according to individual needs to supply basal insulin at predefined rates, which may vary throughout the day and between days, to cover much of the body's functioning. Pumps also allow the user to deliver rapid insulin boluses as required to cover food intake [2]. In Canada, CSII may be used based on patient preference and financial availability, but it is additionally medically indicated in specific patient groups; those who do not reach glycemic targets despite optimized basal-bolus therapy with subcutaneous insulin injections, have significant glucose variability, experience frequent severe hypoglycemia or hypoglycemic unawareness, have rising blood glucose levels in the early morning ('dawn phenomenon'), have very low insulin requirements, report suboptimal treatment satisfaction or quality of life, and in those planning pregnancy [3]. Meta-analysis suggests CSII use improves glycemic control relative to subcutaneous insulin injections with an estimated glycated haemoglobin (HbA1c) reduction of 0.3% (3 mmol/mol), as well as significant improvements in quality of life and treatment satisfaction [4].

With insulin delivery via any medium, blood glucose level monitoring is necessary to help people with diabetes maintain blood glucose levels in safe ranges according to their own health goals. Technology in this area has similarly advanced from initial urine glucose dipsticks to capillary blood glucose strips to the current use of continuous interstitial glucose sensors. Sensors can be

sub-classified into real-time Continuous Glucose Monitoring systems (rtCGM) and intermittently scanned Continuous Glucose Monitoring systems (isCGM, sometimes referred to as flash glucose monitoring), dependent on their method, frequency and duration of blood glucose monitoring. They obtain interstitial glucose readings via a microfilament inserted into subcutaneous tissue, usually on the upper arm. The sensor uses glucose oxidase to generate an electrical signal proportionate to interstitial glucose levels which reflect blood glucose levels, albeit with a lag period. Although glucose readings are collected continuously with isCGM, glucose levels are only available when the sensor is scanned by a reader (this can be a mobile phone with an application to read the sensor or a device specific to the sensor [5]) with retrospective data from device memory being accessible for the preceding eight hours. In contrast, rtCGM continuously displays glucose readings that can be shared remotely to a carer or family member and can also alert the user to the presence of high and low blood glucose levels (hypoglycemia). The latter feature is incorporated in newer isCGM systems (Freestyle Libre 2) [6, 7]. rtCGM systems vary in terms of sensor life and manufacturer calibration requirements, the most recent sensors being the Dexcom G6 and Guardian 3 sensor. The Guardian 3 sensor can be worn for a shorter time period, seven days, compared to ten days with the Dexcom device. Additionally, the Guardian 3 sensor requires two calibrations per day, using finger prick glucose measurements [8]. rtCGM use for between eight and twenty-six weeks in people with type 1 diabetes improves glycemic control relative to self-monitoring of blood glucose [9, 10, 11]. Meta-analysis of observational studies with isCGM use reported a mean HbA1c reduction of 0.55% (6mmol/mol) with 2-4 months of use [12]. rtCGM reduces time spent hypoglycemic, relative to isCGM in patients with hypoglycemic unawareness (GOLD Score ≥4) [13].

However, in Canada, technology for people with type 1 diabetes is expensive. An insulin pump costs $6000-$8000 CAD, pump supplies cost $3000 CAD per year, rtCGM costs $3000-$6000 CAD per year, and isCGM costs $2500 CAD per year [6, 7, 14]. Public coverage of insulin pumps is inconsistent across provinces, with supply restricted by age in some areas [14]. rtCGM is covered by some private plans; public funding is available in British Columbia, Manitoba, Quebec, Saskatchewan, and Yukon as well as through the Ontario Disability Support Program and the Non-Insured Health Benefits Program for First Nations and Inuit [6, 15]. Flash glucose monitoring

(isCGM) is covered by many private insurance plans, but it is currently only publicly funded for those meeting eligibility criteria in Ontario, Quebec, Saskatchewan and Yukon [15]. For individuals living in provinces with limited coverage who do not meet the eligibility criteria of their provincial plan, these high costs present significant barriers to potentially beneficial technology use. Insulin pump use in Canada is more common in provinces with government-funded insulin pump programs, however, even in those provinces with pump funding programs, lower household income is associated with lower frequency of insulin pump use [16].

In this review we highlight the current technological advances in insulin delivery systems available to people with type 1 diabetes in Canada, both approved and off-label. We discuss the implications of the use of these systems for both the user and their healthcare providers (HCP).

1.2 Commercial Automated Insulin Delivery Systems (Commercial AID)

Device companies have manufactured systems to integrate the two described forms of technology; CSII and rtCGM, initially in the form of Sensor Augmented Pumps. These enable interaction between the two systems and have been developed to include a predictive low glucose suspend function [17]. Following on from this, we have seen the introduction of hybrid closed-loop systems (Commercial AID), using predictive algorithms to adjust basal insulin delivery rate based on glucose data overnight and between meals. Described as hybrid, as user input remains required with carbohydrate intake and bolus insulin delivery [18]. These systems are the most technologically advanced, approved, available technology for people with diabetes [8]. Approved Commercial AID systems available in Canada (table 1.1) are the; Medtronic 670G (combines the MiniMed 670G pump and Guardian sensor 3 CGM), Medtronic 770G (MiniMed 770G insulin pump and the Guardian sensor 3) and Tandem Control-IQ (t:slim X2 insulin pump and the Dexcom G6 sensor) [19]. These systems are expensive; currently costing around $8000 CAD, without taking into account pump supplies.

Table 1.1 Components of currently available Automated Insulin Delivery (AID) Systems [17,18, 26, 28, 29]

Commercial AID Systems		
Medtronic 670G *Pump* **-** MiniMed 670G *Sensor* - Guardian 3 with Contour Next Link 2.4 meter for calibration	**Medtronic 770G** *Pump* **-** MiniMed 770G *Sensor*- Guardian 3 and Accu-Chek meter for calibration (Bluetooth connectivity with phone app)	**Tandem Control-IQ** *Pump* **-** t:slim X2 *Sensor* - Dexcom G6 (Bluetooth two-way connectivity with multiple devices including smartphone and CGM)
DIY AID Systems		
OpenAPS *Pump* – Medtronic (512/712, 515/715, 522/722, 523/723 or Veo 554/754) *Sensor*- Dexcom G4/G5/G6, Medtronic Paradigm REAL-Time Revel or Enlite, or Abbott Freestyle Libre *Connecting Hardware*- Micro-computer/ Rig (Intel Edison or Raspberry Pi) and radioboard/stick. Data on small computer or pebble watch.	**AndroidAPS** *Pump* – Medtronic (512/712, 515/715, 522/722, 523/723 or Veo 554/754), DanaR, DanaRS, or Roche (Insight, Accu-Chek Insight or Accu-Chek Combo) *Sensor*- Dexcom G4/G5/G6, Abbott Freestyle Libre, Eversense or Poctech *Connecting Hardware*- None Data on Android Smartphone or watch.	**Loop** *Pump* – Medtronic (515/715, 522/722, 523/723 or Veo 554/754) or OmniPod EROS *Sensor*- Dexcom G4/G5/G6 or Medtronic Enlite *Connecting Hardware*- RileyLink, OrangeLink or EmaLink Data on iPhone or Apple watch.

Commercial AID systems improve glycemic control as well as quality of life, use of the Tandem Control-IQ for at least two months by 1435 individuals, 14 years or older, with type 1 diabetes resulted in a mean 76.7% time in range (TIR) 3.9-10.0mmol/L (71-180mg/dL), after a mean of 24 days use [20]. Users reported a technology acceptance mean score of 49.7 (scores can range -80 to +80), and improvements in both diabetes impact ($p<0.01$) and device satisfaction ($p<0.001$) scores on the DIDS scale with continued use [20]. Similarly, children and adolescents (7-18 years), significantly improved their glycemic control after one month of using the MiniMed 670G system, these improvements were maintained at 12 months follow-up with a TIR of 73.4%, relative to 46.9% at baseline, $p= 0.01$ [21]. However, use of Commercial AID systems is limited by high cost, connectivity issues and concerns about a lack of flexibility in technology type and a lack of customizability, based on individual knowledge and experience of diabetes management [18].

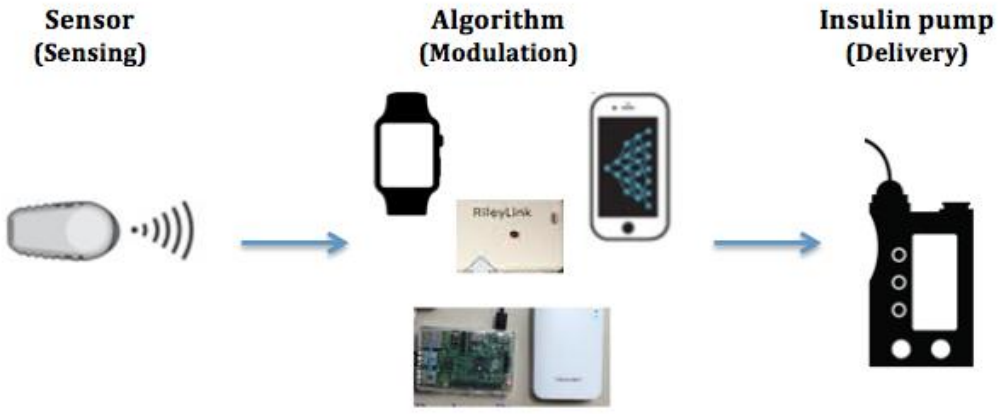
1.3 Do-It-Yourself Automated Insulin Delivery Systems (DIY AID)

Technological advances in commercially available and regulatory approved AIDs have taken time to develop, since initial Medtronic 630G approval by Health Canada in October 2016, and commercial availability from the beginning of 2017 [22]. Dissatisfied with the pace of commercial development and regulatory approvals of Commercial AID, a group of people with type 1 diabetes undertook the development of combining insulin pumps and glucose sensors in a novel and as yet unregulated way [23]. Dana Lewis, from Alabama, USA, initiated the group that developed the first 'Do-It-Yourself Pancreas System' (DIYPS) in 2013. By linking available CSII and rtCGM technologies via a computer system, they created a predictive algorithm that forecast future blood glucose levels and provided personalized recommendations for required changes in insulin supply [24]. In February 2015, this technology progressed into a hybrid closed loop system known as an 'Open Artificial Pancreas System' (OpenAPS), enabling automated micro-adjustments in insulin delivery without the need for intervention by the individual using this system [25]. Through social media platforms and the #WeAreNotWaiting movement, individuals around the world have built their own systems based on this model with support from other users via active online social networks [26].

These DIY AID systems (figure 1.1) can be sub-categorized according to the insulin pumps, communication systems, applications and dosing algorithm which bring these technologies together, broadly into; OpenAPS, AndroidAPS or Loop [25] (table 1.1). OpenAPS, was the first DIY AID system developed by Dana Lewis, Scott Leibrand and Ben West [27]. It uses an oref0 (OpenAPS reference design zero) algorithm that runs on a communicating device (microcomputer). Like commercially available AIDs, DIY AIDs use glucose data from a CGM to determine alterations in basal insulin delivery rate, aiming to keep blood glucose levels within a specified target range between meals and overnight.

Figure 1.1 The Components of a DIY AID System

[15, 24-29]



Without regulatory review and approval, DIY AIDs evolve more rapidly than commercial systems with more options for customization to meet individual needs. For example, an Advanced Meal Assist algorithm is available for adaptable post-prandial dosing of insulin, as well as the additional option of supermicroboluses of insulin to respond to rising blood sugars. The more recent oref1 algorithm aims to completely automate insulin delivery regardless of an individual's changing insulin demand. OpenAPS paired with the Autotune app enables review of glucose data from the preceding twenty-four hours or a user defined time period. Based on these data, it recommends bolus pump setting adjustments including insulin-to-carbohydrate ratio and insulin sensitivity factor [17]. AndroidAPS, first developed in 2017 by Milos Kozak and Adrian Tappe, is similar to OpenAPS, using oref0 and oref1 algorithms. However, rather than a bespoke communication device in the form of a microcomputer, it uses Android smartphones or watches and the newer insulin pumps with Bluetooth capacity. The NSClient app on Android phones enables parents or caregivers to monitor relevant data for their dependents [17, 28]. The Loop algorithm was first developed in 2016, by Nate Rackyleft and Pete Schwamb, with the algorithm running on an iOS operating system. A RileyLink translator, initially designed for use by Schwamb's daughter, Riley, connects the system parts, enabling insulin pump data translation and looping of these data to influence insulin delivery. Loop uses the free app Xcode to covert the raw code into an iOS application; the app can be implemented through an iPhone or apple watch. Loop leaders recommend the Nightscout cloud application to enable access to Loop data, as well as monitoring for parents or caregivers of individuals using this system [29, 30, 31].

DIY AID algorithms are patient-built and patient-dependent. In addition to the underlying technologies required (an insulin pump and rtCGM or isCGM with adjustment device), DIY AID systems require building by the individual themselves. Users are required to access material for set-up on the code-hosting platform GitHub [17]. Set-up may be time intensive and challenging, and support derives from system-specific internet-based resources and the user network [26, 28, 31]. Social media has been a driving force for the development of DIY AID, initially through the use of the #WeAreNotWaiting hashtag on Twitter. In contrast to most healthcare models, social media platforms are the first point of advice for many people using a DIY AID system, serving as an accessible point of contact for the person with diabetes or their care giver(s), at the required

time. The 'Looped' Facebook group, started by Kate Farnsworth, patient partner co-lead for the Innovations in Type 1 Diabetes program for Diabetes Action Canada, is a sharing and advice platform for individuals interested in or currently using Loop systems. This group, a patient-driven support community, now has over 28,000 members worldwide. Multiple Loop-based queries are answered promptly daily, by individuals who have experienced and overcome similar issues with their own systems [32].

1.4 Implications of DIY AID use

Individuals using DIY AID systems report benefits in both their glycemic control and quality of life [33, 34, 35]. Optimal glycemic control may prevent the development and progression of diabetes-related complications [36]. Diabetes Canada recommend a target HbA1c of ≤ 7.0% in most adults with type 1 diabetes, to minimize the risk of both microvascular and cardiovascular complications [37]. However, few adults with type 1 diabetes are able to achieve adequate glycemic control to meet this target [38]. User self-reported data from 18 OpenAPS users indicated achievement of normal HbA1c levels (median change; 7.1 to 6.2%) and substantial improvements in TIR (58 to 81%) [34], to levels higher than those achieved in clinical trials of commercial systems [20, 21]. Individuals choosing DIY AID systems are self-motivated and highly engaged in the management of their diabetes, or their child's diabetes in the case of parents initiating the use of these systems. Primary motivating factors include improving glycemic control and preventing development of complications, as well as improving sleep and alleviating the burden of living with diabetes [35].

The burden of living with diabetes involves time intensive, constant blood glucose level optimization; modification of insulin intake depends on daily alterations in lifestyle, carbohydrate intake and activity levels, in addition to external factors. This burden may result in diabetes specific emotional distress [39], which can be measured by the Diabetes Distress Scale (DDS). This reliable and validated 17-item questionnaire comprises four subcategories; regimen-related distress, emotional burden, inter-personal related distress and physician-related distress, with responses scored on a five item Likert scale [40]. Diabetes specific emotional distress is associated

with poor glycemic control and a major contributing factor is regimen-related distress [39]. Self-reported user data suggest the perceived increase in individual control in self-management of diabetes through regimen choice, with the use of DIY AID systems, can provide a mechanism to reduce the significant emotional burden of living with type 1 diabetes for users of these systems [33] (table 1.2).

Table 1.2 The Proposed Advantages and Disadvantages Associated with using a DIY AID System

Advantages of DIY AID
Improvements in glycemic outcomes Improvements in quality of life Reduction in burden of diabetes Social media support structure Flexibility and choice in type of technology used Constant evolution and improvements in line with user needs
Disadvantages of DIY AID
Lack of regulatory approval Financial costs Time and skill required to set up the system Lack of healthcare provider knowledge and support Potential removal of prescriptions for technology and/or supplies Potential need to use an out of warranty pump

1.4.1 Implications of DIY AID use for Healthcare Providers (HCP)

Widespread use of unlicensed and unregulated insulin delivery systems, presents challenges for healthcare systems and HCP. A lack of legal, ethical and regulatory guidance in the use of DIY AID systems creates uncertainty for HCP with respect to their ethical and professional obligations in providing prescriptions for the technology and associated required supplies [41]. From a clinician's perspective, each component of the DIY AID system that a doctor is responsible for prescribing is an approved medical treatment or device; insulin pump, insulin, glucose sensor and pump supplies. However, individuals using DIY AID systems combine these approved technologies in an unregulated and off-label way.

HCP surveyed (n=317) in the United Kingdom (UK) took a precautionary approach; the majority did not volunteer to discuss the topic of DIY AID systems as a treatment option and only engaged in these conversations if the topic was raised by a patient during their consultation [41]. This worldwide uncertainty has led HCP to question the position of their professional bodies with respect to practice advice, when a patient is using or planning to use a DIY AID system. Guidance from the General Medical Council (GMC), responsible for registration, standard setting and quality assurance of doctors in the UK, advises that 'if prescribing an unlicensed medication, doctors must be satisfied that there is sufficient evidence or experience of using the medicine to demonstrate its safety and efficacy' [42].

The OPEN International Healthcare Professional Network and Open Legal Advisory Group have recently published an international consensus statement, summarizing the current evidence available and practical guidance for HCP in the use of open-source (or DIY) AID [43]. This statement, produced by more than forty specialist HCP and legal experts worldwide, recognizes the potential for both Commercial and DIY AID systems to help a wide population of people with diabetes. It clarifies that it does not support universal application of DIY above Commercial systems and emphasizes the need for HCP to take into account local law and organizational governance in their practice. The statement also highlights the role of representative organizations with regards to challenging legal interpretation and framework in areas where implementation of DIY AID systems is deemed to be unlawful [43].

Specialist country-specific diabetes networks worldwide have also released consensus statements advising their members with regards to best practice relating to DIY AID system use [44-47] summarized in table 1.3. Diabetes UK advised HCP 'should not recommend or initiate discussions regarding DIY AID systems' [44] and the German Diabetes Association (DDG) commissioned a legal evaluation of DIY AID and published its core statements [47]. The Diabetes Poland position statement emphasizes the pressing need to perform studies of these systems with safety measures as primary outcomes and evaluation of their impact on glycemic control and quality of life in safe environments such as hospitals or camps [46]. There has been no formal position statement in the USA, but the American Diabetes Association has addressed the use of these systems in its 2021 Standards of Medical Care in Diabetes document, advising that although these systems cannot be prescribed by HCP, it is important to keep patients safe if they are using them [48].

Table 1.3 Specialist Diabetes Networks Consensus Statements relating to DIY AID use [44-47]

Country	Date	Issuing Group	Advice Summary
Australia	2018	Diabetes Australia	▪ HCP cannot recommend DIY technologies to people with diabetes. ▪ HCP recommendations should be for devices that have been approved through regulatory processes for safety and effectiveness.
Poland	2019	Diabetes Poland	▪ HCP should be as helpful as possible to patients deciding to use DIY AID. ▪ There is a pressing need to perform studies of these systems, with safety measures as primary outcomes, evaluating their impact on glycemic control and quality of life, in safe environments such as hospitals or camps.
UK	2020	Diabetes UK	▪ HCP should continue to offer people who use DIY systems the care and support they are entitled to. ▪ HCP should not recommend or initiate discussions regarding DIY systems.
Germany	2020	German Diabetes Association (DDG)	▪ Physicians have a criminal and liability problem if they carry out active support measures for DIY AID systems. ▪ Physicians should not offer a platform for exchange about DIY AID systems or even training. This can be seen as the application of a medical device contrary to its intended purpose. ▪ The physician has a special position, as the patients confident. A violation of the duty of care can lead to criminal and civil claims.

In Canada, current HCP knowledge, attitudes and practices with regard to these systems across the country are as yet undefined. No consensus statement regarding their use has been released to date by Diabetes Canada. In Canada, health and safety, and professional regulation related to DIY AID system use has additional complexities due to the division of health powers between federal and provincial levels of government [49]. At the federal level, DIY AID algorithms fall under the Health Canada classification of 'Software as a Medical Device' (SaMD) [50]. The Canadian Agency for Drugs and Technology in Health (CADTH) is an independent, not-for-profit organization that evaluates clinical and cost effectiveness of medications, tests, devices and procedures to help inform coverage decisions in all Provinces except Quebec [51]. It defines 'off-label', or expanded use, as any use beyond that which Health Canada has reviewed and authorized to be marketed in Canada. CADTH deems off-label prescribing to be safe, provided there is strong scientific evidence to support it, with a balance of risk and benefit considered [52]. Strong scientific evidence has been defined in this guidance as at least one randomized control clinic trial (RCT) which is a challenging prospect in assessing the efficacy of individually-designed and user-built DIY systems. There are currently no completed RCTs of DIY systems. User self-reported and observational data, however promising, are unlikely to meet this definition of strong scientific evidence to support off-label prescribing of DIY AID [34, 35]. The OPEN Network consensus statement alludes to the challenges of RCTs in this area and supports consideration of real-world evidence in regulatory assessments of DIY systems [43].

If clinicians continue to prescribe for patients using technologies in an 'off-label design' there are questions as to whether knowledge of this method of use, and on-going support of an unapproved method of insulin delivery, could be regarded as negligence. There is the prospect that HCP may be held accountable for these actions in civil court under the law of negligence. A claim of negligence requires the plaintiff to prove on balance of probabilities that the clinician had a duty of care, breached the standard of care and that breach caused harm to the plaintiff [41].

Conversely, it may be suggested that clinicians are breaching expected standards of care and professional obligations if they decline to prescribe and/or care for patients who choose to use

diabetes treatments and devices in an unapproved off-label fashion. Additionally, the role of certified diabetes educators in the use of DIY AID in Canada is another complex domain. Despite not being responsible for prescribing the system components, they are often the first point of contact to troubleshoot patient concerns or issues, giving advice on insulin dose adjustment. These members of the multi-disciplinary diabetes clinical team are also subject to role definitions determined by their respective colleges as governing bodies. In Canada, the regulation of health professionals as well as delivery of healthcare services falls under provincial jurisdiction [49]. It is likely that advice or perspectives that might be provided to HCP would vary depending on the province, their governing body or college, and the respective provincial Health Professions Act [53]. Any potential future guidance for HCP in optimal practice relating to the use of these systems, will need to involve collaboration between these respective bodies to enable consistent patient care throughout Canada. Guidance from expert professional bodies will be helpful to define good clinical practice in this novel domain.

Users of DIY AID systems are effectively 'hacking' commercially available insulin pumps in order to utilize AID. Pump manufacturers have a common law duty to warn users about dangers in the use of their product of which they have knowledge, or should have knowledge. As a minimum, pump manufacturers need to warn users of the potential risks in using their device outside of its approved indications, but this may not be sufficient to protect them from liability [54, 55]. To date there have been no legal cases reported with adverse clinical outcomes relating to DIY AID systems. However, similar to the way that adverse outcomes occur with other insulin delivery methods (for example, accidentally dosing a large amount of fast-acting insulin in place of one's daily injection of slow-acting insulin), it is unfortunately likely to be only a matter of time until an adverse scenario with the use of a DIY AID system does arise and the legal position of both the HCP involved and the insulin pump manufacturer may come into question.

Clinician concerns regarding the legality of their actions is no doubt affecting their consultations with patients using these systems, and is likely to continue to do so until more robust guidelines are in place both nationally and internationally [56]. Guidelines will additionally need to address the advised standing and ethical obligations of HCP when parents or carers initiate these systems

for use in minors; the complexity of this issue has been initially addressed from an Australian perspective, in reference to findings from the Personalised Closed Loop systems for Childhood Diabetes study [57]. It will be important in all of these discussions to consider that "conventional therapy" for type 1 diabetes, which relies on self-management, has substantial intrinsic risks with persons living with diabetes, or their caregivers, having to make choices regarding insulin dosing. Such choices may rely on experience, mental calculations, estimates of carbohydrate content of meals, estimated adjustments for anticipated exercise, or simply guesstimates. This work is burdensome and when it must be done with minimal or no technical systems assisting, it is perhaps unsurprising when people experience adverse outcomes. Using conventional therapy, even when supported in centres of excellence, few patients reach glycemic targets and between 5 and 10% experience severe hypoglycemia – a potentially life-threatening event – every three months [38].

1.4.2 Implications of a lack of guidance on DIY AID use for the person with diabetes

People living with type 1 diabetes and other chronic conditions often have a longstanding and trusting relationship with their clinician and diabetes team, a relationship known to impact upon multiple diabetes-related health outcomes, notably psycho-social well-being [58]. Successful diabetes care with high levels of patient satisfaction and positive health outcomes requires effective patient-clinician communication and shared decision-making [59]. A decision not to discuss DIY AID systems with patients who are interested in such systems, or possibly already currently using them, risks a loss of patient trust in their HCP and a potential breakdown of this patient-clinician relationship. A lack of transparency and shared decision making can impair the caregiving process, with resultant adverse impacts for the person with diabetes, both in terms of their physical and mental health [60]. Patients may be cautious in initiating discussion about their use of DIY AID if their clinician does not raise the topic, as they may doubt the clinician's knowledge or presume negative attitudes towards these systems. They may have concerns about jeopardizing future care including prescriptions and supply of devices and consumables if their HCP is unsupportive of DIY AID systems [23].

As DIY AID systems are individually set-up and designed, the safety of a DIY AID system is reliant on the individual using the system, or their care giver in the case of children using DIY AID. The same, however, can be said for all insulin delivery systems. Inappropriate or mis-programmed pump settings and mistakes made with insulin pens or needles could also result in harm, particularly if used without CGM. Individuals choosing to use DIY systems, however, must be able to navigate and overcome the substantial complexity of building their own system (locating online resources, downloading and compiling computer code etc.), and thus demonstrate substantial technological competence [26, 28, 31], which may go towards mitigating risk. Furthermore, individuals who are using DIY systems are a self-selected group, who are clearly engaged in their diabetes care. There is a diverse range of attributes which may affect suitability for using these systems including educational level, literacy and numeracy skills, diabetes-specific education and experience in carbohydrate counting and glucose monitoring. Socio-economic status, funding/coverage of technologies, family support, and co-morbidities including the presence of diabetes-related distress or obsessive-compulsive tendencies are also important considerations. Clearly, not all people with type 1 diabetes have the same attributes. Therefore, these systems, which may suit and be beneficial for some individuals with type 1 diabetes, may be unhelpful and even harmful for others (table 1.2). Despite rising levels of technology use between 2010-2012 and 2016-2018 among more than 20,000 registry participants with type 1 diabetes in the US, no significant improvement in glycemic control as measured by HbA1c has been observed, in fact a deterioration was seen in adolescents [38]. These data suggest technology alone is not the answer to improving glycemic outcomes in people with diabetes and that diabetes-related education is hugely important, in combination with any technologies implemented.

1.5 Conclusions

People with type 1 diabetes are increasingly using DIY AID systems as their chosen method of insulin delivery in Canada and worldwide. The current knowledge levels, opinions and practices of HCP relating to the use of these systems across the country is unknown. Collecting HCP views

on DIY AID across Canada will be beneficial to target education and inform coherent and appropriate guidance on best practice. The ethical and professional obligations for clinicians caring for patients using these systems urgently need to be clarified, to ensure optimal, consistent and safe patient care.

As DIY AID systems have been designed by patients, there has been no potential for industry funded research or education into their use to date. RCT data is challenging due the patient-designed and individualized nature of these systems. However, data highlighting real-world use of DIY AID is imperative to provide an evidence base to protect their continued and supported use. Currently, the Health Research Council of New Zealand is funding an RCT comparing initially six months of Android APS therapy, to Sensor Augmented Pump therapy, in the CREATE (Community deRivEd AutomaTEd insulin delivery) Trial [61]. The outcomes of this study, in addition to further studies of the OpenAPS and Loop systems, as well Tidepool's push for the first regulatory approved Loop app (based on the DIY Loop AID algorithm) [62] will be important to aid the on-going care of the exponentially increasing number of individuals using this novel and patient-reported highly beneficial method of insulin delivery.

1.6 References

1. Vecchio I, Tornalli C et al. The Discovery of Insulin: An Important Milestone in the History of Medicine. Frontiers in Endocrinology. 2018; 9: 613, 1-8.
2. Kesavadev J, Saboo B et al. Evolution of Insulin Delivery Devices: From Syringes, Pens and Pumps to DIY Artificial Pancreas.
3. McGibbon A, Adams L et al. Diabetes Canada 2018 Clinical Practice Guidelines for the Prevention and Management of Diabetes in Canada: Glycemic Management in Adults with Type 1 Diabetes. Canadian Journal of Diabetes. 2018; 42(1): 80-87.
4. Yeh H, Brown T et al. Comparative Effectiveness and Safety of Methods of Insulin Delivery and Glucose Monitoring for Diabetes Mellitus: A Systematic review and Meta-Analysis. Annals of Internal Medicine. 2012; 157: 336-347.
5. Heinemann L. and Freckmann G. CGM versus FGM; or, continuous glucose monitoring is not flash glucose monitoring. Journal of Diabetes Science Technology. 2015; 9: pp.947-950.
6. Diabetes Canada. Continuous Glucose Monitoring (CGM), available at https://www.diabetes.ca/DiabetesCanadaWebsite/media/Managing-My-Diabetes/Tools%20and%20Resources/Continuous_Glucose_Monitoring_Advocacy_Pkg_4.pdf?ext=.pdf, last accessed 27th December 2021.
7. Diabetes Canada. Flash Glucose Monitoring, Jan 2020, available at https://www.diabetes.ca/DiabetesCanadaWebsite/media/Managing-My-Diabetes/Tools%20and%20Resources/Flash_Glucose_Monitoring.pdf, last accessed 27th December 2021.
8. Leelarathna L, Choudhary P et al. Hybrid closed-loop therapy: where are we in 2021? Diabetes, Obesity and Metabolism. 2020; 23(3): 655-660.
9. Beck R, Riddlesworth T et al. Effect of Continuous Glucose Monitoring on Glycemic Control in Adults with Type 1 Diabetes using Insulin Injections. JAMA. 2017; 317(4): 371-378.
10. Lind M, Polonsky W et al. continuous Glucose Monitoring vs Conventional Therapy for Glycemic Control in Adults with Type 1 Diabetes Treated with Multiple Daily Insulin Injections: The GOLD Randomized Clinical Trial. JAMA. 2017; 317(4): 379-387.

11. Thabit H, Prabhu J et al. Use of Factory Calibrated Real-time Continuous Glucose Monitoring improves Time in Target and HbA1c in a Multiethnic cohort of Adolescents and Young Adults with type 1 diabetes: The MILLENIAL Study. Diabetes Care. 2020; 14: 42.
12. Evans M, Welsh Z et al. The Impact of Flash Glucose Monitoring on Glycaemic Control as Measured by HbA1c: A Meta-analysis of Clinical Trials and Real-world Observational Studies. Diabetes Therapy. 2020; 11(1): 83-95.
13. Reddy M, Jugnee M et al. A randomized control pilot study of continuous glucose monitoring and flash glucose monitoring in people with type 1 diabetes and impaired awareness of hypoglycaemia. Diabetic Medicine. 2018; 35(4): 483-490.
14. Diabetes Canada. Coverage of Insulin pumps across Canada, March 2020, available at https://www.diabetes.ca/DiabetesCanadaWebsite/media/Advocacy-and-Policy/Advocacy%20Reports/Insulin-Pumps-Comparison-EN.pdf, last accessed 17th December 2021.
15. JDRF June 2021. Available at https://www.jdrf.ca/two-wins-for-continuous-glucose-monitoring-cgm-devices-in-quebec-and-british-columbia/, last accessed 16th December 2021.
16. Song C, Booth G, Perkins B and Weisman A. Impact of government-funded insulin pump programs on insulin pump use in Canada: a cross-sectional study using the National Diabetes Repository. BMJ Open Diabetes Research & Care. 2021;9:e002371.
17. Beato-Vibora P, Gallego-Gamero F and Ambrojo-Lopez A. Real-world outcomes with different technology modalities in type 1 diabetes. Nutrition, Metabolism and Cardiovascular Disease. 2021; in press.
18. Kesavadev J, Srinivasan S et al. The Do-It-Yourself Artificial Pancreas: A Comprehensive Review. Diabetes Therapy. 2020; 11: 1217-1235.
19. The diaTribe Foundation. Health Canada Clears MiniMed770G Automated Insulin Delivery system, available at https://diatribe.org/health-canada-clears-minimed-770g-automated-insulin-delivery-system, last accessed 29th December 2021.

20. Pinsker J, Muller L et al. Real-World Patient Reported Outcomes and Glycemic Results with Initiation of Control IQ Technology. Diabetes technology and therapeutics. 2021; 23(2): 120-127.
21. Petrovski G, Al Khalaf F et al. One-year experience of hybrid closed-loop system in children and adolescents with type 1 diabetes previously treated with multiple daily injections: drivers to successful outcomes. Acta Diabetologica. 2021; 58(2): 207-213.
22. Medtronic announces Health Canada Licence of the Minimed 630G, available at www.medtronic.com/ca-en/about/news/minimed-630G-system.html, last accessed 23rd December 2021.
23. Lewis D. History and Perspective on DIY Closed Looping. Journal of Diabetes Science and Technology. 2019; 13(4): 790-793.
24. Lewis DM. Automated Insulin Delivery: How artificial pancreas closed-loop systems can aid you living with type 1 diabetes, available at https://diyps.org/2019/06/05/automated-insulin-delivery-how-artificial-pancreas-closed-loop-systems-can-aid-you-in-living-with-diabetes-introducing-the-aps-book-by-danamlewis/ , last visited 21st December 2021.
25. Lewis DM. DIYPS: About Dana Lewis, available at https://diyps.org/about/dana-lewis/, last visited 21st December 2021.
26. Open APS, available at https://openaps.org, last visited 27th December 2021.
27. Crabtree TSJ, McClay A and Wilmot EG. DIY artificial pancreas systems: here to stay? Practical Diabetes. 2019; 36: 63-68.
28. AndroidAPS Documentation, available at https://androidaps.readthedocs.io/en/latest/index.html, last accessed 27th December 2021. https://androidaps.readthedocs.io/en/latest/index.html
29. Diabetech: Looping. What is it? Available at https://www.diabettech.com/looping-a-guide/what-is-it/, last visited 27th December 2021.
30. Racklyeft N. The history of Loop and Loopkit: Reflecting on the past in celebration of version 1.0, available at https://medium.com/@loudnate/the-history-of-loop-and-loopkit-59b3caf13805, last accessed 24th December 2021.

31. LoopDocs, available at https://loopkit.github.io/loopdocs/, last accessed 5th December 2021.
32. Looped Facebook Group available at www.facebook.com/groups/TheLoppedGroup, last accessed 7th January 2022.
33. OpenAPS.org, Open APS Outcomes, available at https://openaps.org/outcomes, last accessed 24th December 2021.
34. Lewis D and Leibrand S. Real-World Use of Open-Source Artificial Pancreas Systems. Journal of Diabetes Science and Technology. 2016; 10(6): 1411.
35. Jennings P and Hussain S. Do-It-Yourself Artificial Pancreas Systems: A Review of the Emerging Evidence and Insights for Healthcare Professionals. Journal of Diabetes Science and Technology. 2019; 14(5): 868-877.
36. Nathan DM, Genuth S et al. Diabetes Control and Complications Trial Research Group: The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. NEJM. 1993; 329(14): 977-986.
37. Imran SA, Agarwal G et al. Diabetes Canada: Targets for Glycemic Control. Chapter 8. Available at https://www.diabetes.ca/health-care-providers/clinical-practice-guidelines/chapter-8#panel-tab_FullText, last accessed 27th December 2021.
38. Foster M, Beck R et al. state of Type 1 Diabetes Management and Outcomes from the T1D Exchange in 2016-2018. Diabetes Technology and Therapeutics. 2019; 21(2): 66-72.
39. Strandberg S, Graue M et al. Longitudinal relationship between diabetes-specific emotional distress and follow-up HbA1c in adults with Type 1 diabetes mellitus. Diabetic Medicine. 2015; 32(10): 1304-1310.
40. Polonsky W, Fisher L et al. Assessing psychosocial distress in diabetes: development of the diabetes distress scale. Diabetes Care. 2005;28:626-631.
41. Shaw D, Crabtree TSJ et al. The DIY Artificial Pancreas system: An Ethical Dilemma for Doctors. Diabetic Medicine. 2020; 37: 1952.
42. General Medical Council. Good Practice in prescribing and managing medicines and devices. 2013; available at https://www.gmc-uk.org/ethical-guidance/ethical-guidance-

for-doctors/prescribing-and-managing-medicines-and-devices, last accessed 18th December 2021.

43. Braune K, Lal R et al. Open-source automated insulin delivery: international consensus statement and practical guidance for health-care professionals. Lancet Diabetes and Endocrinology. Nov 2021;21:00267-9.
44. Dowling L, Wilmot EG, Choudhary P. Diabetes UK Position Statements. Do-it-yourself closed-loop systems for people living with type 1 diabetes. Diabetic Medicine. 2020: 37: 1977-1980.
45. Diabetes Australia. Position Statement: People with Type 1 Diabetes and Do-It-Yourself (DIY) Technology Solutions, available at https://www.diabetesaustralia.com.au/wp-content/uploads/DIY-solution-position-statement.pdf, last accessed 29th December 2021.
46. Gawrecki A, Klupa T et al. Utilization of do-it-yourself artificial pancreas systems in the management of patients with type 1 diabetes: a position statement of the Pump School Education Initiative by Diabetes Poland. Polish archives of internal medicine. 2019; 129(2): 141-142.
47. Heinemann L and Lange K. "Do It Yourself" (DIY)—Automated Insulin Delivery (AID) Systems: Current Status from a German Point of View. Journal of Diabetes Science and Technology. 2020; 14(6): 1028-1034.
48. American Diabetes Association. 7. Diabetes Technology: Standards of Medical Care in Diabetes 2021, available at https://care.diabetesjournals.org/content/44/Supplement_1/S85, last accessed 27th December 2021.
49. Watts M. Health Law in Canada. Osler. 2014, available at https://www.osler.com/PDFs/Resource/en-ca/Health-Law-in-Canada.pdf, last accessed 29th December 2021.
50. Health Canada. Guidance Document: Software as a Medical Device (SaMD): Classification Examples. 2019. Available at https://www.canada.ca/en/health-canada/services/drugs-health-products/medical-devices/application-

information/guidance-documents/software-medical-device-guidance/examples.html#a1, last accessed 29th December 2021.

51. CADTH. About the Health Technology Assessment Service. June 2021. Available at https://www.cadth.ca/about-health-technology-assessment-service, last accessed 29th December 2021.
52. CADTH Tool: Off-label drug use. July 2017, available at https://www.cadth.ca/sites/default/files/pdf/off_label_use_of_drugs_pro_e.pdf, last accessed 27th December 2021.
53. Government of Ontario. 1991. Regulated Health Professions Act, 1991. SO 1991, C.18. Retrieved December 6, 2021. <http://www.elaws.gov.on.ca/html/statutes/english/elaws_statutes_91r18_e.htm>.
54. Buchan v. Ortho Pharmaceutical (Canada) Ltd., 1986 CanLII 114 (ON CA), <https://canlii.ca/t/1npp9>, retrieved on 2021-12-30.
55. Hollis v. Dow Corning Corp., 1995 CanLII 55 (SCC), [1995] 4 SCR 634, <https://canlii.ca/t/1frdr>, retrieved on 2021-12-30.
56. Roberts JTF, Moore V and Quigley M. Prescribing Unapproved Medical Devices? The Case of DIY Artificial Pancreas Systems. Medical Law International. 2021.
57. Johnson C. Good enough? Parental decisions to use DIY looping technology to manage type 1 diabetes in children. Monash Bioethics Review. 2021; July.
58. Beverly EA, Ganda OP, Ritholz MD. Look who's (not) talking: Diabetic patients' willingness to discuss self-care with physicians. Diabetes Care. 2021; 35(7): 1466-1472.
59. Von Korff M, Gruman J et al. Collaborative management of chronic illness. Ann Intern Med 1997;127: 1097–1102.
60. Beverly EA Worley M et al. Patient-Physician Communication and Diabetes Self-Care. Journal of Clinical Outcomes and Management. 2016; 23: 11.
61. de Bock, Lewis M et al. The CREATE (Community deRivEd AutomaTEd insulin delivery) Trial, available at https://www.otago.ac.nz/christchurch/departments/paediatrics/research/otago717634.html, last accessed 27th December 2021.

62. Look H. 99 Years closer: About our FDA submission of Tidepool Loop, available at https://www.tidepool.org/blog/99-years-closer-about-our-fda-submission-of-tidepool-loop, last accessed 23rd December 2021.

Chapter 2: A Scoping Review of Do-It-Yourself Automated Insulin Delivery System (DIY AID) Use in People with Type 1 Diabetes

2.1 Introduction

Do-It-Yourself Automated Insulin Delivery (DIY AID) systems comprising; AndroidAPS, OpenAPS and Loop, categorized by the technology and computerized algorithm they incorporate, have not gone through regulatory approval processes [1]. Despite this, these systems are rapidly gaining in popularity worldwide with a notable social media presence through the #WeAreNotWaiting movement [2]. People with type 1 diabetes are choosing to use these systems to enable flexible self-management of their condition, with a desire for improved quality of life [3].

Improved glycemic and long-term health outcomes are the two most frequently reported motivating factors for individuals choosing to use a DIY system [4]. Glycated haemoglobin (HbA1c), is the traditional measure of longer-term glucose levels; an assessment of the preceding three months, which provides a marker of risk for the development of long-term diabetes-related complications [5]. More recently, the increasing use of Continuous Glucose Monitoring (CGM) has enabled assessment of three key concepts; time in range (TIR) usually 3.9-10.0mmol/L, time above range (TAR) and time below range (TBR) to further assess glycemic variability. Consensus recommendations suggest aiming for TIR >70%, corresponding with an HbA1c of 7%. Suggested targets for TAR and TBR are <25% and <4%, with targets for both proportion of time and glucose levels needing adjustment dependent upon individual factors, notably in the elderly, higher risk people with diabetes, and during pregnancy [6]. The avoidance of hypoglycemia, imperatively severe hypoglycemia (SH); a blood glucose level below target range requiring the assistance of a third party to treat, should be prioritized in preference to optimizing TIR [7].

Healthcare providers (HCP) worldwide are challenged by the novel and unregulated approach to diabetes care that DIY AID poses. These are systems which the majority of HCP have limited experience with, and unlike most healthcare processes, have been instigated and set up by the person with diabetes, rather than with the support of their healthcare team [2]. Providing the technology and medical supplies required for the continued use of these systems, with the knowledge that their patients are using them in an unregulated way, has potential ethical

implications for HCP [8]. The uncertainty surrounding ethical, legal and liability considerations continue to result in inconsistent care for people with diabetes choosing to use these systems worldwide [9].

Conflicting guidance for professionals regarding DIY AID use has been issued by specialist diabetes networks in Europe and Australia [10-13], with some recommending prioritization of patient choice and support [10, 12], while others highlight the prospects of criminal and liability issues if actively supporting patient's use of these systems [13]. The need for further outcome studies in the use of these systems has been highlighted as a priority by Diabetes Poland, with safety as a primary outcome, in order to enable physicians to support their patients to achieve the associated benefits of DIY AID, with the suggestion of hospitals or camps as potential safe locations to perform these novel studies [12].

We performed a scoping review of the currently available literature surrounding DIY AID systems, specifically to highlight the evidence available to support their use. We aimed to identify studies reporting on the impact of DIY AID systems on type 1 diabetes management for both users and their care givers, or HCP, with the goal of collating outcome data; glycemic variability, safety and quality of life. In addition, we hoped to gain a greater understanding of the experiences of DIY AID system users and HCP providing care for people using these systems.

2.2 Methods

This review was carried out in accordance with the Enhancing Transparency in Reporting the Synthesis of Qualitative Research (ENTREQ) criteria [14] (table 2.1.4, appendices). A thematic synthesis methodology was used for analysis; with heterogeneity seen in the incorporated study designs (case reports, qualitative, cross-sectional and cohort studies), but consistency in the reported outcome measures. This methodology enables translation of concepts across studies, with organization of descriptive themes and transparency in analysis of the study results [15].

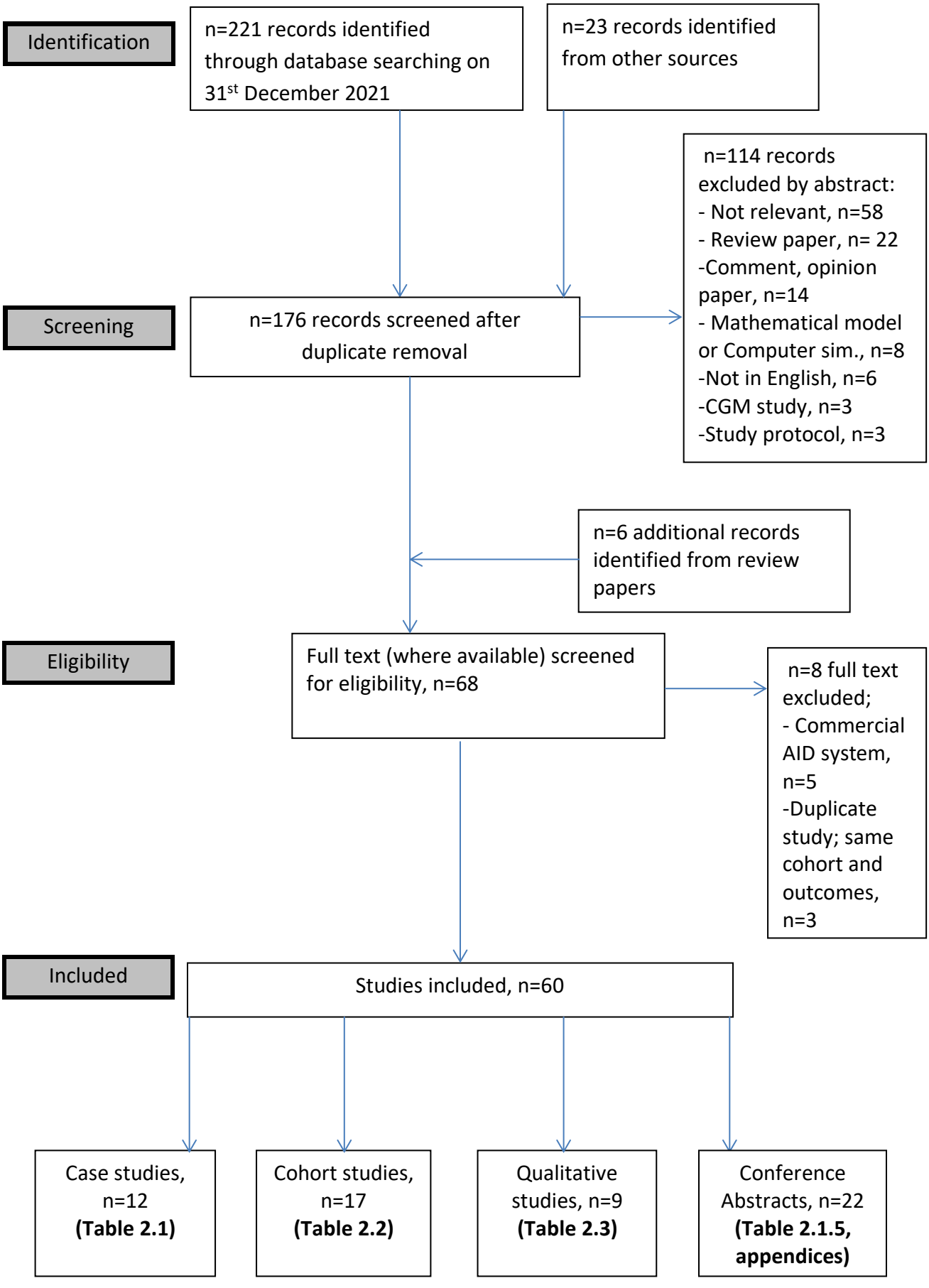
2.2.1 Data sources and searches

A review was conducted of the available literature in the use of DIY AID systems, published until 31st December 2021. Relevant articles published in English were systematically sought using the databases Embase, Medline, Web of Science, Scopus, Proquest and Cochrane library. Terms were searched as keywords within the title or abstract of the manuscript, combining the description of the disease of interest (type 1 diabetes) and those used in the description of DIY AID systems (do-it-yourself, loop, automated insulin delivery or artificial pancreas system), the full search strategy is shown in figure 2.1.1, appendices. Additional grey literature searches took place through the search engine 'Google', reviewing the first 10 pages of results in the search 'DIY' and 'type 1 diabetes' on 31st December 2021. Relevant conference abstracts were additionally searched in the available listings for the past two years at the American Diabetes Association (ADA 2019, 2020), Diabetes UK (DUK 2020, 2021) and Advanced Technologies & Treatments for Diabetes (ATTD 2020, 2021) conferences.

2.2.2 Study selection

Two independent reviewers (AM and KC) screened the identified titles after implementing the search strategy (figure 2.1.1, appendices), for those deemed to be relevant, review of abstract and full text (where available) took place. Article type and which AID system used were assessed. Case reports/case series, qualitative studies, prospective cohorts, retrospective cohorts, cross-sectional studies and conference abstracts were included for review (PRISMA Flowchart in figure 2.1). Only studies in humans, published in English, reporting on the use of the DIY AID systems; OpenAPS, AndroidAPS or Loop were included in the results. Reference lists of both included studies and review articles were screened for any additional relevant studies requiring inclusion into this review.

Figure 2.1 PRISMA Flowchart



2.2.3 Quality assessment

The identified cohort group DIY AID studies were sub-classified according to the data collection method; into qualitative, prospective and retrospective cohort or cross-sectional studies. Quality assessment of full text, excluding case report studies, was carried out using the Clinical Appraisal Skills Program checklist for qualitative and cohort studies (table 2.1.1 and table 2.1.2, appendices) and AXIS (the Appraisal Tool for Cross-Sectional studies) for the identified cross-sectional studies (table 2.1.3, appendices). These are validated checklists, according to study type, looking broadly at the domains of aims, methodology, results, analysis, overt findings and implications of these on future practice, with each domain assessed as 'yes', 'no' or 'can't tell' [16, 17, 18].

2.2.4 Analysis

For all relevant study and text types identified, reporting qualitative or quantitative results in the use of DIY AID systems, data was extracted on; first author, year of publication, geographical area, study methodology, participants, outcomes and measurement of these outcomes. Common themes were identified in the outcomes reported across the DIY AID cohort studies and the results reported within these outcome themes. The themes identified comprised; glycemic variability, safety, quality of life, healthcare provider attitudes and social media. Glycemic data are reported using a standardized TIR of 3.9-10.0 mmol/L, unless otherwise stated.

2.3 Results

Following implementation of the search strategy (figure 2.1.1, appendices), 244 potentially relevant articles were reduced down to 68 full texts, after exclusion through screening of title and abstract (PRISMA, figure 2.1). Following detailed assessment, 60 studies reporting on the use of DIY AID systems were included in our results, these comprised; 12 case reports/case series, 17 cohort studies, 9 qualitative studies and 22 conference abstracts.

Quality assessment revealed high-quality study design across the included study types with quality consideration throughout study aims, methodology, recruitment processes, consideration of ethical issues, data analysis and reporting of findings. However, in 8 of the 9 reported qualitative studies it was unclear as to whether the relationship between the researcher

and participant had been considered by the study team. Of the included cohort studies, 6 studies identified possible confounders in outcomes, but none of these studies considered confounders in data analysis. The deficiencies highlighted in cross-sectional study quality were a lack of consideration of response bias and no documentation of ethical approval for the study (each identified in 3 of the 8 studies).

2.3.1 DIY AID Case reports

The main characteristics of the case report studies are shown in table 2.1 [19-30]. These 12 articles, report DIY AID use in a total of 20 individuals (70% female); 12 Loop, 5 AndroidAPS and 3 OpenAPS. The study outcomes report HbA1c (% or mmol/mol) in 10 studies, with HbA1c value pre-DIY system use additionally available in 5 of these studies, with 80% reporting an improvement in HbA1c with DIY AID use. TIR is a reported outcome in 10 of the studies, with pre-DIY AID TIR values available in 2, and an improvement in TIR with DIY AID use demonstrated in both of these. Diabetes related quality of life score (dQOL) and fear of hypoglycaemia (HFS-II) were reported outcomes in one case report, with improvements seen with Loop use [27].

Pregnancy use of DIY AID is reported in 10 individuals with; Loop (n=7), AndroidAPS (n=2) and OpenAPS (n=1) [23, 26, 28-30]. TIR according to pregnancy targets (3.5-7.8mmol or 63-140mg/dL) was > 70% in every trimester in seven of these ten individuals. One study compared glycemic outcomes for the same individual in a pregnancy using AndroidAPS to a previous pregnancy managed using multiple daily injections (MDI) of insulin, with improvement in TIR with the use of the DIY AID system in each trimester; TIR vs previous pregnancy; trimester 1: 74 vs 51%, trimester 2: 76 vs 71% and trimester 3: 77 vs 69%. TBR (<63mg/dL) was superior in the first trimester and similar for the rest of pregnancy; TBR vs previous pregnancy; trimester 1: 9 vs 12%, trimester 2: 12 vs 13% and trimester 3: 14 vs 13% [23].

Case reports additionally discussed the beneficial impact of DIY AID use in people with type 1 diabetes in situations where maintaining stable blood glucose levels would be challenging; running a half marathon [22] and fasting during Ramadan [25].

2.3.2 DIY AID Cohort Studies

The 17 cohort studies relating to DIY AID use, described in table 2.2 [4, 31-46], comprised cross-sectional (n=8), retrospective (n=6) and prospective (n=3) studies, relating to the use of AndroidAPS (n=4), OpenAPS (n=2), Loop (n=1) or a combination of the three system types (n=10). HCP opinions on DIY AID systems were reported in 4 studies, and 15 studies reported user opinions and/or their outcomes with DIY AID use. The USA contributed to the production of the greatest number of cohort studies (n=5, 29%), in addition to Germany (n=3), United Kingdom (n=3), Czech Republic (n=2), Switzerland (n=1), Australia (n=1), China (n=1) and Poland (n=1).

2.3.3 DIY AID Qualitative Studies

The 9 qualitative studies identified relating to DIY AID use, described in table 2.3 [47-55], comprised interview studies (n=5), analysis of Twitter data (n=2), a workshop summary (n=1) and analysis of study coordinator meetings (n=1). The majority of these studies (n=6) reported on the outcomes with a combination of the three DIY AID system types. Participants included; users (5 studies), care givers (2 studies), HCP (2 studies), mentors in the DIY AID community (1 study, 9 participants), people with type 1 diabetes not currently using a DIY AID system (1 study, 16 participants), as well as people that had decided to stop using Loop (1 study, 45 participants).

2.3.4 DIY AID Conference Abstracts

The 22 conference abstracts identified relating to DIY AID use, described in table 2.1.5, appendices [56-77] were published as part of ATTD (n=10), ADA (n=7), Diabetes UK (n=3), Annual Diabetes Technology Meeting (n=1) and the International Society for Pediatric and Adolescent Diabetes (n=1) conferences. These abstracts comprised case reports/case series (n=5), qualitative (n=4) and retrospective (n=9), cross-sectional (n=3) and prospective (n=1) cohort studies.

2.3.5 Glycemic variability

Self-reported retrospective user data looking at glycemic variability with OpenAPS use was first published by Lewis in 2016, with 18 participants reporting improved HbA1c (mean 6.2 vs 7.1% prior to OpenAPS use) and TIR (80-180mg/dL); (81 vs 57% prior to OpenAPS) [31]. Further data on OpenAPS outcomes was published by Melmer in 2019, through retrospective analysis of 80 users' CGM data, that had been uploaded to the OpenAPS Data Commons Repository. Of these,

34 users had additional data available from Sensor-augmented insulin pump (SAP) use prior to OpenAPS; with a mean reduction in HbA1c of 0.4% and increase in TIR of 9.3%, relative to SAP use [34].

Sole use of AndroidAPS was studied in 4 of the observational studies, both retrospective (n=2) and prospective (n=2), including a total of 85 participants. AndroidAPS implementation ranged from a minimum of three nights, up to six months duration [33,40,42,43]. The three studies with a minimum of three months AndroidAPS use, all reported improvements in HbA1c and TIR from baseline. The largest of these by Petruzelkova et al, followed 36 children; 18 pre-school (age 3-7 years) and 18 school age (age 8-14 years), for six months following switching from SAP to AndroidAPS. Glycemic outcomes improved in the pre-school children with AndroidAPS in comparison to SAP use; HbA1c 48.5 vs 53.8mmol/mol and TIR 78.6 vs 70.8%. This improvement with AndroidAPS use was also demonstrated in the school age children; HbA1c 45.1 vs 52.6mmol/mol and TIR 82.9 vs 77.2% [42].

With Loop, one prospective observational study followed 558 participants for six months, after initiation of Loop. TIR (70-180mg/dL) and HbA1c were compared from baseline therapy, to after six months of Loop use with improvement seen in both of these parameters with Loop in comparison to baseline therapy; mean TIR 73 vs 67% and HbA1c 6.5% vs 6.8% [41].

Glycemic outcomes with a combination of DIY AID system types were reported in 6 studies, including 5 self-reported user outcome studies, and a retrospective observational cohort. Self-reported user outcomes involved a total of 1508 participants worldwide, with all studies reporting improvements in TIR and/or HbA1c with DIY AID use [4,32,35,39,46]. Jeyaventhan et al reported retrospective observational glycemic data with six months of DIY AID use in 30 individuals (50% Loop, 36.7% AndroidAPS, 13.3% OpenAPS), comparative to the same time period for 38 users of Commercial AID (Medtronic 670G). DIY AID users demonstrated greater HbA1c reduction and improved TIR relative to Commercial AID; 0.9 vs 0.1% and 78.5% vs 68.2% [44].

The cohort studies reporting data for changes in glycemic outcomes with DIY AID use were user self-reported (n=4) and observational (n=6). HbA1c reduction ranged in self-reported studies;

from 0.64-0.9% [4,31,35] and in observational studies; 0.3-0.9% [33-34,40-43]. Improvement in TIR, self-reported; 16.5-23% [4,31,35,46] and observational; 0-11.3% [33-34,40-43]. The OpenAPS Data Common Repository data (80 users), demonstrated mean HbA1c reduction of 0.4% and TIR increase 9.3% [34]. In the conference abstracts, glycemic outcomes were reported in 9 observational studies, with a minimum of 1 month and maximum 11 months duration of DIY AID use. Mean HbA1c achieved ranged 6.1-6.6%, and a TIR 77.6-87.8% with DIY AID [56-58,60-63,66,70]. Mean HbA1c reduction across the abstracts reporting change relative to baseline insulin delivery method; ranged 0.3-0.84%, with mean increase TIR 6.4-22.7% [56-58,60,66]. Two abstracts compared DIY AID to CSII with Freestyle Libre use, for a minimum of one month; a mean increase of 24.8-27.7% TIR was reported with the DIY systems [61,70].

2.3.6 Safety

The frequency of episodes of hypoglycemia (n=2), SH (n=2) and TBR (n=7) were reported in a total of 9 studies [32-34,39-44], with improvements in these parameters reported with the use of all three DIY AID system types. TBR was reduced by 0.1-1.11% across the observational studies [40,41, 43]. Two observational studies reported no improvement in TBR [33 and 42] using Android APS, time spent 3.0-3.8mmol/L remained static at 3% in pre-school age children, and increased from 2.6 to 3.8% in school age children using AndroidAPS for six months, relative to baseline SAP [42]. An increased TBR, with three nights AndroidAPS use in 22 children was reported relative to SAP; 5% vs 3% [33]. In user self-reported studies (n=2), 17.9% [39] and 74% [32] of users reported a reduction in the frequency of hypoglycaemia with the use of DIY AID.

Gawrecki et al, reported primary outcomes of both safety and glycemic control, reporting no cases of SH or Diabetic Ketoacidosis (DKA) in twelve weeks of AndroidAPS use. A reduction in time <54mg/dL (0.1%), and time <70mg/dL (0.75%), was demonstrated in 12 participants, relative to baseline CSII [43]. No episodes of DKA were reported in 68 both Commercial and DIY AID users, in the 6-month retrospective study by Jeyaventhan et al, TBR was 3.2% DIY and 2.6% Commercial AID. This study additionally reported a non-significant increase in SH in users of Commercial relative to DIY AID [44].

In the 8 conference abstracts reporting TBR, mean TBR with DIY AID ranged 2.5-4.9% [56-59,61-63,70]. A mean reduction in TBR 0.6-6.07% relative to baseline therapy was reported [56-59,62]. Relative to users of Freestyle Libre with CSII, DIY AID use was associated with 3.2% reduction in TBR [61,70]. No hospital admissions or episodes of SH were stated with OpenAPS use, for a mean duration of 11 months in 9 adult users [61].

2.3.7 Quality of life

Quality of life was assessed by Wu et al in 15 participants with 3 months of AndroidAPS use, through the use of the EuroQol Five-Dimension 5-Level Health Questionnaire (EQ-5D-5L), both in the form of utility index (UI) and visual analogue scale (VAS). Improvement in mean score with AndroidAPS use, was seen in VAS relative to baseline; 82 vs 77 (of a maximum 100), but no change demonstrated in UI, mean 0.88 vs 0.88 (of a maximum 1). A small improvement was seen in diabetes-related distress; an increase from 6 to 9% in those scoring little or no diabetes distress, and a reduction in fear of hypoglycemia relative to baseline therapy through use of the Hypoglycaemia Fear Survey II- Worry Scale (HFS-II); mean score 22.13 vs 26.27 (lower score better, of a maximum 72) [40]. Self-reported improved sleep quality was highlighted by 94% of OpenAPS users [31], and 79% of DIY AID users [32]. When questioned regarding the main benefits of DIY AID, 22.5% of 86 participants, reported better sleep quality/nightly safety [39]. Assessment of the motivations to commence DIY AID, revealed 71% of adults and 80% of caregivers cited improved sleep quality as a motivating factor for this choice of insulin delivery system [4].

An abstract for ADA by Hood et al, assessed quality of life outcome measures both before and after 3 months of using Loop, in 254 new Loop users. Improvements were seen in mean scores of diabetes-related distress, as measured by the diabetes distress scale (DDS); 2.06 to 1.66 (scored from 1; not a problem, to 6; a very significant problem). A reduction in fear of hypoglycemia (HFS-II); 19.74 to 17.18, and improvement in sleep were also demonstrated, (Pittsburgh Sleep Quality Inventory, scored 0 to 21); 6.82 to 5.39 [64]. In a cross-sectional study abstract for ATTD, Zabinsky et al explored self-reported outcomes with DIY AID in 180 users; 74.7% reported improved sleep quality/quantity, 69.4% reduced time spent managing diabetes and 76.9% reduced diabetes-related stress [65].

2.3.8 Healthcare provider (HCP) attitudes

HCP opinions on DIY AID use were collected in 4 studies, 3 from the USA and one from the UK, with a total of 753 HCP surveyed [36-38,45]. In the UK study of 317 HCPs, 91% of participants advised they would not initiate discussions about DIY AID and 2% reported that they perceived the systems as dangerous [37]. One study from the USA, surveyed 152 HCP approached via the American Association of Diabetes Educators, 27% reported that they perceived these systems as safe [38]. A lack of understanding in how the systems work was reported by 74.4% of participants, 11.6-34.9% felt comfortable answering questions about DIY AID systems [36] and 97% reported a willingness to learn more about them [37]. Fear of HCP disapproval of DIY AID was reported as a prominent reason for users who had decided to stop using Loop [55]. In a survey of 104 school nurses, 23% reported a child using DIY AID attended their school, 46% stated they had no prior knowledge of DIY AID and 96% felt the child should be able to share their data with a parent or guardian during the school day [45]. HCP supporting AndroidAPS use as part of the Community Derived Automated Insulin Delivery study (CREATE) in New Zealand [78,79], found that user challenges with this system most frequently related to device issues (the insulin pump and cannula in 24% of analyzed conversations), as opposed to DIY AID specific challenges [53].

Cohen et al reported a qualitative interview study of the perceived benefits and barriers of DIY AID use in 20 HCP working in pediatric and adult diabetes services in the UK, as an abstract for ATTD. Of the 20 participants, 19 reported liability concerns and lack of formal guidelines to be barriers to supporting the current use of DIY AID in widespread clinical practice [73].

2.3.9 Social media

Attitudes from users and the DIY AID community were collected through 6 studies using social media (Facebook and Twitter), with 2 reporting the content of Tweets [47, 50], and 4 using these platforms to distribute surveys to DIY AID users [32,35,38,46]. A total of 49,925 tweets were analyzed from 8214 participants [47,50]. User opinions of DIY AID across these studies were positive, with 82-85% positive interactions on Twitter [47]. Through an interview study, mentors in the DIY AID community, largely through the use of social media platforms, reported altruism

as the main reason behind their role, and the frequency of questions and managing workload, to be the biggest challenges they face [49].

Of the conference abstracts reviewed, 2 detailed the recruitment of participants through the use of social media. A qualitative interview study of 11 girls and women, discussing glycemic variability and need for algorithm adjustment relating to hormonal changes, recruited study participants through topic related discussion on social media [72]. Girelli et al, distributed a survey via the Looped and OpenAPS Facebook groups, gaining responses from 120 respondents interested in DIY AID use and 19 current users [68].

2.4 Discussion

The findings of this scoping review highlight that there is a large, and rapidly expanding body of published outcome data relating to DIY AID system use. Social media platforms have provided both a source to gather large quantities of user data, as well as a means for recruitment of study participants. In addition, we have found online resources and social media, especially Facebook and Twitter, to be a large part of the support structure for people using DIY AID [49, 52], with the Looped Facebook group now having over 28,000 members [80]. This however, is not a conventional method to collect data relating to pharmaceutical and technological advances, and will bring the validity of the reported results into question, with the prospect of selection bias in addition to the seemingly very favorable user outcomes being self-reported. However, in this scoping review, we have evidence of impressive and consistent glycemic outcomes with DIY AID use; improvements in TIR, HbA1c and TBR, and have seen no great discrepancies between the outcomes reported in observational studies relative to this self-reported data [4,32,34,35,39-44,46].

Current users of DIY AID systems are in themselves self-selected, the systems are user-built and individualized. The development of the technology in DIY AID has been driven by the user from its outset, rather than a pharmaceutical company, making it challenging to collect impartial and externally valid data on its use, as well as to fund large clinical trials [2]. This individualized user choice in method of insulin delivery for management of type 1 diabetes, brings into question

both the appropriateness and the utility of randomized control trials (RCT), in the setting of these systems.

It is challenging to compare results between the studies reviewed, as well as between the DIY AID system types, due to the variable design and duration of the studies described, in addition to the inclusion criteria for participants. We have reviewed observational data relating to the use of AndroidAPS (85 participants) [33,40,42,43], with three of these studies implementing the system for a minimum of three months (63 participants), all demonstrating improvement in mean HbA1c and TIR [40,42,43]. An observational study of Loop (558 participants) from the USA highlighted similar improvements in HbA1c (0.3%), TIR (7%) and a reduction in TBR (0.1%). Notably these observational improvements in glycemic outcomes, were all within in the first six months of Loop use, in individuals with already close to optimal glycemic control; mean HbA1c at baseline 6.8% [41]. These glycemic outcomes are not representative of the 'average' person with type 1 diabetes, with just 21% of American adults with type 1 diabetes reaching an HbA1c of less than 7% (53mmol/mol) [81]. This reiterates the concept that users of DIY AID do not represent a 'typical' person with diabetes, and that the outcomes demonstrated with these systems in observational studies are largely a reflection of the individual that is choosing to use this technology, in conjunction with the merits of the system itself. There is questionable generalizability of the results across the studies we have reviewed, to the implementation of these systems in the wider population of people with diabetes. Despite the overwhelmingly positive outcomes in both the observational studies and self-reported data, we cannot infer from this that these systems are the optimal glucose management system for all people with type 1 diabetes.

In order to set up these seemingly very beneficial systems, a level of understanding of both the technology and type 1 diabetes management is needed. User input and understanding of carbohydrate counting, insulin:carbohydrate ratios and insulin sensitivity factors are required to set up and optimize DIY AID use, the technology alone is not enough [82]. In addition to diabetes education, a level of both literacy and numeracy skills are needed to follow the instructions for system set up and to overcome any barriers that may be faced in this process [83-85]. The studies

reviewed highlight the importance of internet resources, social media platforms as well as mentors in the DIY AID community in guiding users through the set up and any on-going challenges with these systems. This community of users and advisors have much greater experience in the use of these systems than the majority of HCP [82].

Currently, the appropriate role of HCP in DIY AID is not clear and the studies of HCP knowledge and attitudes in the use of these systems reflect this uncertainty. Due to the novelty and rapidly evolving nature of these systems, the majority of HCP caring for people with diabetes have not received any formal system-specific education whilst training for their roles. With the rising popularity of DIY AID worldwide, the majority of HCP working in the specialty of Endocrinology and Diabetes, are now likely to be the responsible clinician for one or more person using some form of DIY AID [8]. With a lack of training in their use, as well as unresolved ethical and potentially medico-legal concerns, it is unsurprising that the majority of HCP are not voluntarily broaching the subject of DIY AID systems in consultations with people with type 1 diabetes [37]. A lack of system-specific training, and open communication with potential future as well as current DIY AID users, results in compromised and inconsistent care for people with diabetes. In an attempt to rectify this, the OPEN International Healthcare Professional Network and OPEN Legal advisory group have recently published a consensus statement, with practical guidance for HCP in the use of DIY or open-source AID [86]. This group, comprising specialist HCP and legal experts in the field of AID systems make reference to the challenges in supporting users of an unregulated system and the need to take into account local law and organizational governance in clinical practice.

Active support of an 'off-label' medical device, such as DIY AID, requires strong clinical evidence which is, defined as a minimum of one RCT in Canada [87]. Despite the broad scope of evidence to support DIY AID use highlighted by this review; beneficial glycemic outcomes, quality of life measures and supportive safety data, no RCT has been completed. An RCT protocol is in progress in New Zealand; comparing six months of Android APS to Sensor Augmented Pump therapy [78]. This study is funded by the Health Research Council of New Zealand and includes both children and adults [79]. The OPEN consensus statement makes reference to the difficulties we have

discussed, in performing an RCT in the use of DIY AID, suggesting the extensive real-world data available, that we have highlighted in this scoping review, should be considered in regulatory approval processes [86].

2.5 Conclusion

There is a vast and rapidly expanding body of observational and self-reported user data available in the use of DIY AID systems. There are however substantial potential weaknesses in these studies, with inclusion of biased samples presenting challenges in the generalizability of this real-world evidence. No RCTs have been completed for any of the three DIY AID system types; the standardized method to achieve conclusive, unbiased, level 1 evidence. This may however not be the optimal data collection methodology in the assessment of outcomes with this self-selecting, individualized and user-built technology choice. In contrast to the evidence supporting commercially available AID systems, an objective unbiased data deficiency for DIY AID and lack of regulatory approval is resulting in uncertainty worldwide among HCP. Education and best practice recommendations for HCP are lacking, in the utilization of OpenAPS, AndroidAPS and Loop systems. These interventions are imperative to enable appropriate and optimal HCP support for people with type 1 diabetes choosing to use these glucose management systems. Mentors within the DIY AID community have been highlighted as rich knowledge sources, who could play a key and essential role, in developing focused education and training programs, in this exciting and rapidly expanding field.

2.6 References

1. Crabtree TSJ, McClay A and Wilmot EG. DIY artificial pancreas systems: here to stay? Practical Diabetes. 2019; 36: 63-68.
2. Lewis D. History and Perspective on DIY Closed Looping. Journal of Diabetes Science and Technology. 2019; 13(4): 790-793.
3. OpenAPS.org, Open APS Outcomes, available at https://openaps.org/outcomes, last accessed 4th January 2022.
4. Braune K, Gajewska K et al. Why #WeAreNotWaiting—Motivations and Self-Reported Outcomes Among Users of Open-source Automated Insulin Delivery Systems: Multinational Survey. Journal of Medical Internet Research. 2021; 23(6).
5. Nathan DM, Genuth S et al. Diabetes Control and Complications Trial Research Group: The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. NEJM. 1993; 329(14): 977-986.
6. Battelino T, Danne T et al. Clinical Targets for Continuous Glucose Monitoring Data Interpretation: Recommendations from the International Consensus on Time in Range. Diabetes Care. 2019; 42(8):1593-1603.
7. Yale JF, Paty B and Senior PA. Diabetes Canada Clinical Practice Guidelines Expert Committee: Chapter 14 Hypoglycemia. Available at https://www.diabetes.ca/health-care-providers/clinical-practice-guidelines/chapter-14#panel-tab_FullText, last accessed 28th February 2022.
8. Shaw D, Crabtree TSJ et al. The DIY Artificial Pancreas system: An Ethical Dilemma for Doctors. Diabetic Medicine. 2020; 37: 1952.
9. Roberts JTF, Moore V and Quigley M. Prescribing Unapproved Medical Devices? The Case of DIY Artificial Pancreas Systems. Medical Law International. 2021.
10. Dowling L, Wilmot EG, Choudhary P. Diabetes UK Position Statements. Do-it-yourself closed-loop systems for people living with type 1 diabetes. Diabetic Medicine. 2020: 37: 1977-1980.

11. Diabetes Australia. Position Statement: People with Type 1 Diabetes and Do-It-Yourself (DIY) Technology Solutions, available at https://www.diabetesaustralia.com.au/wp-content/uploads/DIY-solution-position-statement.pdf, last accessed 2nd January 2022.
12. Gawrecki A, Klupa T et al. Utilization of do-it-yourself artificial pancreas systems in the management of patients with type 1 diabetes: a position statement of the Pump School Education Initiative by Diabetes Poland. Polish archives of internal medicine. 2019; 129(2): 141-142.
13. Heinemann L and Lange K. "Do It Yourself" (DIY)—Automated Insulin Delivery (AID) Systems: Current Status From a German Point of View. Journal of Diabetes Science and Technology. 2020; 14(6): 1028-1034.
14. Tong A, Flemming K, McInnes E, Oliver S, Craig J. Enhancing transparency in reporting the synthesis of qualitative research: ENTREQ. BMC Med Res Meth. 2012;12:181.
15. Thomas J and Harden A. Methods for the thematic synthesis of qualitative research in systematic reviews. BMC Medical Research Methodology. 2008; 8: 45.
16. Critical Appraisal Skills Programme. CASP (qualitative checklist) checklist 2018. Available at https://casp-uk.b-cdn.net/wp-content/uploads/2018/03/CASP-Qualitative-Checklist-2018_fillable_form.pdf. Accessed 2nd January 2022.
17. Critical Appraisal Skills Programme. CASP (cohort study checklist) checklist 2018. Available at https://casp-uk.b-cdn.net/wp-content/uploads/2018/03/CASP-Cohort-Study-Checklist-2018_fillable_form.pdf. Accessed 2nd January 2022.
18. Downs MJ, Brennan ML, Williams HC and Dean RS. Development of a critical appraisal tool to assess the quality of cross-sectional studies (AXIS. BMJ Open. 2016; 6 (12).
19. Marshall D, Holloway M et al. Do-It-Yourself Artificial Pancreas Systems in Type 1 Diabetes: Perspectives of Two Adult Users, a Caregiver and Three Physicians. Diabetes Therapy. 2019; 10(5):1553-1564.
20. Patton MA. One year of DIY looping after 38 years of type 1 diabetes Australia Diabetes Educator. 2019; 22(2), available at https://myartificialpancreas.net/2019/07/09/one-year-of-diy-looping-after-38-years-of-type-1-diabetes/, last accessed 4th January 2022.

21. Duke M and Fredlock A. Do-it-yourself (DIY) systems in diabetes: A family and provider perspective. Journal of Diabetes Science and Technology. 2020. 14 (5):917-921.
22. Braune K, May M and Thurm U. Safe and Successful Completion of a Half Marathon by an Adult With Type 1 Diabetes Using a Personalized Open Source Artificial Pancreas System. Journal of Diabetes Science and Technology. 2020; 14(6): 1137-1138.
23. Schutz-Fuhrmann I, Schutz A et al. Two Subsequent Pregnancies in a Woman With Type 1 Diabetes: Artificial Pancreas Was a Gamechanger. Journal of Diabetes Science and Technology. 2020; 14(5): 972-973.
24. Ahmed S, Ewens D et al. Do-It-Yourself (DIY) Artificial Pancreas Systems for Type 1 Diabetes: Perspectives of Two Adult Users, Parent of a User and Healthcare Professionals. Advances in Therapy. 2020; 37(9): 3929-3941.
25. Ahmed S and Gallo S. Looping with Do-It-Yourself Artificial Pancreas Systems During Ramadan Fasting in Type 1 Diabetes Mellitus: Perspectives of a User and a Physician. Diabetes therapy. 2020; 9:1-11.
26. Lemieux P, Yamamoto J and Donovan L. Do-It-Yourself Artificial Pancreas System Use in Pregnant Women With Type 1 Diabetes in a Real-World Setting: 2 Case Reports. Canadian Journal of Diabetes. 2021; 20:S1499-2671.
27. Kesavadev J, Saboo B, Kar P and Sethi J. DIY artificial pancreas: A narrative of the first patient and the physicians' experiences from India. Diabetes & metabolic syndrome. 2021; 15(2): 615-620.
28. Waiker AR, Arora T et al. Case Report: Managing Pregnancy with Type 1 Diabetes using a do-it-yourself Artificial Pancreas System. Clinical Diabetes. 2021. Vol 39 (4): 441-444.
29. Schutz AK, Schutz-Fuhrmann I et al. Management of type 1 diabetes mellitus using open-source automated insulin delivery during pregnancy: a case series. Diabetes Technology and Therapeutics. 2021. 0.1089/dia.2021.0260.
30. Bukhari K and Malek R. Open-source automated insulin delivery systems for the management of type 1 diabetes during pregnancy. BMJ Case Report. 2021. 14:e243522.
31. Lewis D and Leibrand S. Real-World Use of Open-Source Artificial Pancreas Systems. Journal of diabetes science and technology. 2016; 10(6): 1411.

32. Hng TM and Burren D. Appearance of Do-It-Yourself closed-loop systems to manage type 1 diabetes. Internal Medicine Journal. 2018; 14 (11): 1400-1404.
33. Petruzelkova L, Soupal J et al. Excellent Glycemic Control Maintained by Open-Source Hybrid Closed-Loop AndroidAPS During and After Sustained Physical Activity. Diabetes technology & therapeutics. 2018; 20(11): 744-750.
34. Melmer A, Zuger T et al. Glycaemic control in individuals with type 1 diabetes using an open-source artificial pancreas system (OpenAPS). Diabetes, obesity & metabolism. 2019; 21(10): 2333- 2337.
35. Braune K, O'Donnell S et al. Real-World Use of Do-It-Yourself Artificial Pancreas Systems in Children and Adolescents with Type 1 Diabetes: Online Survey and Analysis of Self-Reported Clinical Outcomes. JMIR mhealth and uhealth. 2019; 30(7):7.
36. Murray J, Clayton M and Litchman M. Health Care Provider Knowledge and Perceptions of FDA-Approved and Do-It-Yourself Automated Insulin Delivery. Journal of diabetes science and technology. 2020; 14(6): 1017-1021.
37. Crabtree TSJ, Choudhary P et al. Health-care professional opinions of DIY artificial pancreas systems in the UK. Lancet Diabetes and Endocrinology. 2020; 8(3): 186-187.
38. Palmer W, Greely S, Letourneau-Frieburg LR, Naylor R. Using a Do-It-Yourself Artificial Pancreas: Perspectives from Patients and Diabetes Providers. Journal of Diabetes science and technology. 2020; 14(5): 860-867.
39. Herzog AL, Busch J et al. Survey about do-it-yourself closed loop systems in the treatment of diabetes in Germany. PLoS One. 2020; 15(12): 0243.
40. Wu Z, Luo S et al. Use of a do-it-yourself artificial pancreas system is associated with better glucose management and higher quality of life among adults with type 1 diabetes. Therapeutic advances in endocrinology and metabolism. 2020; 25:11: 204.
41. Lum J, Bailey R et al. A Real-World Prospective Study of the Safety and Effectiveness of the Loop Open-Source Automated Insulin Delivery System. Diabetes technology & therapeutics. 2021; 23(5): 367-375.

42. Petruzelkova L, Jiranova P et al. Pre-school and school-aged children benefit from the switch from a sensor-augmented pump to an AndroidAPS hybrid closed loop: A retrospective analysis. Paediatric Diabetes. 2021; 22(4): 594-604.
43. Gawrecki A, Zozulinska-Zoilkiewicz D et al. Safety and glycemic outcomes of do-it-yourself AndroidAPS hybrid closed-loop system in adults with type 1 diabetes. PLoS One. 2021; 5: 16(4).
44. Jeyaventhan R, Gallen G, Choudhary P and Hussain S. A real-word study of user characteristics, safety and efficacy of open-loop closed-source systems and Medtronic 670G. Diabetes, Obesity and Metabolism. 2021. Online ahead of print.
45. March C, Oyetoro R et al. School Nurse Perspectives of Do-it-Yourself Artificial Pancreas systems in the School Setting. Diabetes Technology and Therapeutics. 2021. 26; online ahead of print.
46. Street TJ. Review of Self-Reported Data from UK Do-It-Yourself Artificial Pancreas System (DIYAPS) Users to Determine Whether Demographic of Population Affects Use or Outcomes. Diabetes Therapy. 2021.
47. Litchman M, Lewis D, Kelly L and Gee P. Twitter Analysis of #OpenAPS DIY Artificial Pancreas Technology Use Suggests Improved A1C and Quality of Life. Journal of diabetes science and technology. 2019; 13(2): 164-70.
48. Quintal A, Messier V et al. A Qualitative Study of the Views of Individuals with Type 1 Diabetes on the Ethical Considerations Raised by the Artificial Pancreas. Narrative enquiry in Bioethics. 2020; 10(3).
49. Crocket H. Peer Mentoring in the Do-it-Yourself Artificial Pancreas System Community. Journal of diabetes science and technology. 2020; 14(6): 1022- 1027.
50. Litchman M, Walker H et al. Patient-Driven Diabetes Technologies: Sentiment and Personas of the #WeAreNotWaiting and #OpenAPS Movements. Journal of diabetes science and technology. 2020; 14(6): 990-999.
51. Shepard J, Breton M et al. User and Healthcare Professional Perspectives on Do-It-Yourself Artificial Pancreas Systems: A need for Guidelines. Journal of Diabetes Science and Technology. 2020.

52. Schipp J, Skinner T et al. How Adults with Type 1 Diabetes Are Navigating the Challenges of Open-Source Artificial Pancreas Systems: A Qualitative Study. Diabetes technology & therapeutics. 2021; 10:1089.
53. Crocket H, Lewis D et al. Learning Challenges of Health Care Professionals Supporting Open-Source Automated Insulin Delivery. Diabetic Medicine. 2021; e14750.
54. Schipp J, Skinner T et al. 'We're all on the same team'. Perspectives on the future of artificial pancreas systems by adults in Australia with type 1 diabetes using open-source technologies: A qualitative study. Diabetic Medicine. 2021' e14708.
55. Wong J, Suttiratana S. Discontinued use of the Loop Insulin Dosing System: A Mixed-Methods Investigation. Diabetes Technology and Therapeutics. 2021; e0362.
56. Lewis D, Swain R and Donner T. Improvements in A1C and Time-in-Range in DIY Closed-Loop (OpenAPS) Users. Diabetes. 2018; 67(suppl 1).
57. Choi S. Open Artificial Pancreas System Improved Glycemic Control and Quality of Life in patients with type 1 diabetes. Journal of Diabetes Science and Technology. 2018 Mar; 12(2).
58. Choi SB, Hong ES and Noh YH. Open artificial pancreas system reduced hypoglycemia and improved glycemic control in patients with type 1 diabetes. Diabetes. 2018;67(suppl 1).
59. Provenzano V, Guastamacchia E, et al. Closing the loop with OpenAPS in people with type 1 diabetes—experience from Italy. Diabetes. 2018;67(suppl 1).
60. Braune K, O'Donnell S et al. DIWHY: Factors Influencing Motivation, Barriers, and Duration of DIY Artificial Pancreas System Use among Real-World Users. Diabetes 2019 Jun; 68(Supplement 1).
61. Wilmot EG, Langeland L, Mclay A and Taylor N. 1067-P: open-source artificial pancreas system (APS) vs. combination insulin pump with flash glucose monitoring in adults with type 1 diabetes: an observational study. Diabetes. 2019;68:1067-P.
62. Jiranova P, Soupal J et al. An AndroidAPS Hybrid Closed Loop system in a home setting is safe and leads to better metabolic control. ATTD. 2019; 0270:191.

63. Zabinsky J, Howell H et al. Do-it-yourself artificial pancreas systems for type 1 diabetes reduce hyperglycemia without increasing hypoglycaemia. Diabetes. 2020;Jun;69(suppl 1).
64. Hood K, Wong J et al. Do-it-yourself (DIY) Loop is associated with Psychosocial benefits. Diabetes. 2020;Jun:69(suppl 1).
65. Zabinsky J, Buchanan J and Wond J. User perceptions and satisfaction with do-it-yourself closed-loop systems for type 1 diabetes. ATTD. 2020;268/234.
66. Wu Z, Luo S et al. Use of do-it-yourself hybrid closed-loop is associated with better glucose management and higher quality of life among adults with type 1 diabetes. ATTD. 2020;267/266.
67. Garfinkel J. My life as a practical cyborg: A T1D's reflection on Loop and the DIY bio-hack movement. ATTD. 2020;205/674.
68. Girelli A, Gariboldi D et al. First Italy DIY APS users survey. ATTD. 2020; 239/800.
69. White S, Reid A et al. 'Looping' through pregnancy by a woman with type 1 diabetes. Diabetic Medicine. 2020; 37(S1).
70. Patel R, Crabtree TSJ et al. Glycaemic Outcomes of do-it-yourself artificial pancreas systems (DIY APS) verses Freestyle Libre (FSL) with concomitant insulin pump therapy (CSII): A cross-sectional comparison from the Royal Derby Hospital cohort. Diabetic Medicine. 2021;38(S1):P226.
71. Patel R, Crabtree TSJ et al. Do-it-yourself artificial pancreas systems (DIY APS): Qualitative analysis of patient's perspectives of quality of life and glucose outcomes. Diabetic Medicine. 2021;38(S1):P225.
72. Mewes D and Braune K. Qualitative analysis of subjectively perceived glycemic variations and therapy adjustments with respect to the menstrual cycle in girls and women using an open source automated delivery system. Pediatric Diabetes. 2021; 22(S1): EP039.
73. Cohen L, Naranjo D et al. Do it yourself Automated Insulin Dosing: Qualitative study exploring healthcare professional experiences. ATTD. 2021;O024/173.

74. Dowden S and Hudson B. Paris-Brest-Paris: Ultra-endurance cycling with type one diabetes using an open-source artificial pancreas system. ATTD. 2021;P050/30.
75. Cohen L, Barnard-Kelly K et al. Do-it-yourself Automated Insulin Dosing: Qualitative study exploring user experiences. ATTD. 2021;P053/172.
76. Alidibbiat A, Alqashami A and Hussain S. An observational study detailing clinical experience, Safety and Efficacy of Commercial and Open-source Automated Insulin Delivery systems in fasting during Ramadan with type 1 diabetes.ATTD. 2021;P056/397.
77. Treiber G, Novak E, Hantschel E and Mader J. Challenges with DIY Loop in pregnancy with type one diabetes. ATTD.2021;P278/107.
78. Burnside M, Lewis D et al. CREATE (Community deRivEd AutomaTEd insulin delivery) trial. Randomised parallel arm open label clinical trial comparing automated insulin delivery using a mobile controller (AnyDANA-loop) with an open-source algorithm with sensor augmented pump therapy in type 1 diabetes. Journal of diabetes and metabolic disorders. 2020; 19(2): 1-15.
79. de Bock, Lewis M et al. The CREATE (Community deRivEd AutomaTEd insulin delivery) Trial, available at https://www.otago.ac.nz/christchurch/departments/paediatrics/research/otago717634.html, last accessed 4th January 2022.
80. Looped Facebook Group available at www.facebook.com/groups/TheLoppedGroup, last accessed 7th January 2022.
81. Foster M, Beck R et al. state of Type 1 Diabetes Management and Outcomes from the T1D Exchange in 2016-2018. Diabetes Technology and Therapeutics. 2019; 21(2): 66-72.
82. Leelarathna L, Choudhary P et al. Hybrid closed-loop therapy: where are we in 2021? Diabetes, Obesity and Metabolism. 2020; 23(3): 655-660.
83. AndroidAPS Documentation, available at https://androidaps.readthedocs.io/en/latest/index.html, last accessed 7th January 2022.
84. LoopDocs, available at https://loopkit.github.io/loopdocs/, last accessed 5th January 2022.
85. Open APS, available at https://openaps.org, last visited 7th January 2022.

86. Braune K, Lal R et al. Open-source automated insulin delivery: international consensus statement and practical guidance for health-care professionals. Lancet Diabetes and Endocrinology. Nov 2021;21:00267-9.
87. CADTH Tool: Off-label drug use. July 2017, available at https://www.cadth.ca/sites/default/files/pdf/off_label_use_of_drugs_pro_e.pdf, last accessed 5th January 2022.

First Author (Year)	Country (PMID)	System	Participants	Outcomes	Results
Marshall (2019)	UK (31440989)	1. AndroidAPS 2. OpenAPS 3. Loop	3 patient experiences; 2 male, 1 female during pregnancy	HbA1c (mmol/mol), TIR with DIY AID (using TIR 4-10 in 1, 3.6-14 in 2 and 3.5-7.8 mmol/mol in 3)	1. 43, 85-90% 2. 45.4, 91% 3. 42, 80%
Patton (2019)	Australia (n/a)	OpenAPS	50 yr. female, with 38-year history of T1D	Glycemic outcomes Qualitative impact on day-to-day life	HbA1c reduction to 6%, increased TIR. QoL benefits; usability of technology and convenience.
Duke (2020)	USA (32131623)	Loop	Parent perspective starting Loop for son	HbA1c Loop vs pre-DIY Quality of Life	6.3 vs 8.1% Family feel 'more rested and more balanced and are able to think about something other than diabetes'
Braune (2020)	Germany (31709805)	AndroidAPS for 23 months	49-year-old male, T1D for 32 years, running a half marathon	Race completion TIR during race Hypoglycaemia	Race completed in 1hr 52 mins 100% No hypoglycemia
Schutz-Fuhrmann (2020)	Austria (32059616)	Pregnancy 1-MDI and Flash glucose monitoring Pregnancy 2-AndroidAPS	37-year-old female, during two pregnancies; Pregnancy 1 age 35 years Pregnancy 2 age 37 years	Pregnancy 2 with AndroidAPS; HbA1c TM1 TM2 TM3 TIR (63-140mg/dL) TM 1 TM2 TM3 TBR TM1 TM2 TM3 Birth weight	(vs Pregnancy 1 with MDI and Flash GM) 6.3 vs 5.9% 5.1 vs 5.1% 5.0 vs 4.9% 74 vs 51% 76 vs 71% 77 vs 69% 9 vs 12% 12 vs 13% 14 vs 13% 2900 vs 2820g
Ahmed (2020)	UK (32696329)	1.Loop 2.Loop 3. AndroidAPS	1. 31-year-old female 2. 18-year-old male 3. 10-year-old male	HbA1c, TIR with DIY AID	(vs previous insulin delivery) 1. 5.5 vs 6.5%, 90-95% 2. 42 vs 70mmol/mol, 80% vs 60% 3. Glycemic data not available

Ahmed (2020)	UK (32922559)	Loop	Muslim female with T1DM fasting during Ramadan	CGM data during the month of Ramadan. Comparative experience to Medtronic 670G use previously	Enabled this person with diabetes to fast during Ramadan with customizable settings
Lemieux (2021)	Canada (33648862)	1.Loop 2.OpenAPS	1.31-year-old female Loop use from 13 months pre-pregnancy 2.40-year-old female- OpenAPS use from 3 months pre-pregnancy	HbA1c pre-conception, TIR (3.5-7.8mmol/L) TM 1/2/3, TBR TM1/2/3, Mean HbA1c during pregnancy, Delivery; Date, Birth Weight user 1 and 2.	1. 6.2%, 71.6/72.9/81.3%, 4.6/4.1/2.3%, 5.7%, 38+5, 3070g 2. 5.1%, 87.5/86.6/89.1%, 1.9/1.8/2.0%, 5.0% 39+1, 3440g
Kesavadev (2021)	India (33725629)	Loop	24-year-old female	With Loop use; HbA1c TIR Fear of hypoglycemia and QOL	(vs CSII) 6.2 vs 7.2% 90-95 vs <60% Improvements in HFS-II and Dqol with Loop
Waiker (2021)	USA (34866788)	Loop	30-year-old female, Loop use pre conception and during pregnancy	One month pre- conception; HbA1c TIR (70-180mg/dL) TBR TM 1/2/3 TIR (64-140mg/dL) TBR Time <54mg/dL Pregnancy outcomes including birth weight	 6.0% 77% 5% 62.8/66/76.5% 3.7/4.6/4.3% 0.9/2.1/1.1% Induction 39/40 with unplanned C-section, BW = 2910g, 24hrs in NICU – hypoglycemia
Schutz (2021)	Austria (34542371)	Loop (3 users) AndroidAPS (1 user)	3 Loop users during pregnancy; 36, 26, 28 years old.	Pre-pregnancy HbA1c (user 1,2,3,4) TIR (63-140mg/dL) TM1 TM 2 TM 3	5.7, 5.9, 6.2, 6.5% 78.4, 77, 61.3, 74% 85.8, 80.4, 78.6, 76.0% 88.8, 82.2, 82.0, 77%

			1 AndroidAPS user during pregnancy; 39 years old.	Pregnancy outcomes; date at delivery (weeks), birth weight.	40, 37+4, 39+1, 38+5 3040, 3750, 3600, 2900g
Bukhari (2021)	USA (34535491)	Loop	40-year-old female, Loop use during pregnancy and 6 months pre-conception	Pre-conception HbA1c TIR TM 1/2/3 TBR TAR Birth weight Type and timing of delivery	6.4% 66/68/72% 6/5/7% 28/27/21% 3742g Emergency C-section, 37 weeks, no neonatal complications

Table 2.1 DIY AID Case Control Studies [19-30]

First Author (Year)	Country (PMID)	AID System (Study type)	Participants	Outcomes	Results
Lewis (2016)	USA (27510442)	OpenAPS (Retrospective cohort)	18 users; 12 male, 6 female. Median; age 27yrs, 15 years of diabetes, 10 years CSII and 3 years CGM use.	Self-report measures: HbA1c TIR (80-180mg/dL) Improved sleep quality	(vs pre OpenAPS) 6.2 vs 7.1% 81 vs 58% 94% reported
Hng (2018)	Australia (30387315)	OpenAPS, AndroidAPS and Loop (Cross-sectional)	Online survey posted to Australian Loop Facebook group. 68 respondents, 20 Loopers, 4 carers of Loopers.	Loopers (%) reported improvements in; TIR Sleep Hypoglycaemia frequency HbA1c, Confidence Energy Mood swings	 100 79 74 68 47 37 32
Petruzelkova (2018)	Czech Republic (30285476)	AndroidAPS vs SAP (Prospective cohort)	22 children, 6-15 years, 16 female, 6 male during alpine ski sports camp, for three consecutive days and nights.	With AndroidAPS; Mean glucose level TBR TIR	(vs SAP) 7.2 vs 7.7 mmol/L 5 vs 3% 82 vs 82%
Melmer (2019)	Switzerland (31183929)	OpenAPS (Retrospective cohort)	Analysis of anonymized CGM records of 80 users uploaded to the OpenAPS Data Commons repository; 19495 days or 53.4 years of total data. 34 of the users had additional CGM data when previously using Sensor Augmented Pump (SAP) to compare.	With OpenAPS; Mean glucose TIR TBR <3.0mmol/L >10mmol/L >13.9 mmol/L Change relative to SAP; mean glucose, HbA1c TIR <3.0mmol/L Coefficient of variation	 7.6mmol/L 77.5% 4.3% 1.3% 18.2% 4.1% -0.6mmol/L -0.4% +9.3% -0.7% -2.4%

Braune (2019)	Germany with virtual survey respondents from 21 countries (31364599)	AndroidAPS (48%) OpenAPS (28.4%) Loop (28.4%) (Retrospective cohort)	Online survey distributed via Facebook groups; 209 participants, 47.4% female, median age 10 years (range 3-20), median duration DIYAID 7.5months. Self-reported outcomes by person with diabetes or caregivers pre and post DIYAID use.	Mean HbA1c after initiation; ALL DIY AndroidAPS OpenAPS Loop Mean TIR after initiation; ALL DIY AndroidAPS OpenAPS Loop	(vs pre-DIY) 6.27 vs 6.91% 6.24 vs 6.85% 6.36 vs 7.1% 6.39 vs 6.99% 80.68 vs 64.2% 79.5 vs 63.8% 81.7 vs 67.1% 79.1 vs 64.2%
Murray (2020)	USA (31876176)	AndroidAPS, OpenAPS and Loop (Cross-sectional)	Phase 1 – paper-based survey, 43 HCPs, 90.7% female. Phase 2- online survey, 137 HCPs, 93% female, 91% nurses and nutritionists.	HCP experiences with DIY and Commercial AID, barriers to answering questions about DIY AID.	11.6% (DIY), 34.9% (Commercial) comfortable answering questions relating to these systems, 74.4% report lack of understanding how DIY AID systems work.
Crabtree (2020)	UK (32085825)	AndroidAPS, OpenAPS and Loop (Cross-sectional)	Survey Monkey link for HCP, 317 respondents; 46% consultants, 38% diabetes specialist nurses or dieticians, 27% HCPs in paediatrics.	Initiation of conversations about DIYAPS and reasons why, perception of DIYAPS as dangerous, willingness to support users and learn more about DIYAPS.	91% would not initiate conversations, 2% perceived DIYAPS as dangerous, 55% willing to support users, 97% wished to learn more about DIYAPS.
Palmer (2020)	USA (32680447)	AndroidAPS, OpenAPS and Loop (Cross-sectional)	User survey via Facebook and Twitter; 101 participants. HCP survey via the American Association of Diabetes Educators; 152 participants.	User self-reported glycemic control and safety. HCP perception safety DIY AID.	94% patients reported improved TIR. 89% users reported the systems to be safe, relative to 27% HCP.

Herzog (2020)	Germany (33332410)	AndroidAPS, OpenAPS and Loop (Cross-sectional)	Survey of 1054 people with diabetes, 86 respondents using DIY closed loop; 92% using AndroidAPS.	Mean self-reported TIR DIY Reported HbA1c improvement using DIY AID. Positive perceived aspects of DIY AID Negative aspects DIY	79.5% 91% stated HbA1c improvement 43.8% better TIR, 22.5% better sleep quality, 17.9% fewer hypoglycemic episodes, 10.1% better disease management. Complexity of system 14.6%, lack of institutional approval 4.5%.
Wu (2020)	China (32922721)	AndroidAPS (Retrospective cohort)	15 participants; 10 females, median age 32.2 years, diabetes duration 9.7years with a minimum of 3 months continuous AndroidAPS use after SAP at baseline.	After 3 months AndroidAPS; HbA1c Mean glucose TIR TBR Fear of hypoglycaemia, Diabetes distress (little/no distress), EQ-5D-5L VAS	(vs SAP at baseline) 6.79 vs 7.63% 7.43 vs 8.03 mmol/L 84.28 vs 75.01% 1.72 vs 2.83% 22.13 vs 26.27 points (max 72) 9 vs 6% 82 vs 77 points (max 100)
Lum (2021)	USA (33226840)	Loop (Prospective cohort)	558 new Loop users (<7days), age range 1-71 years, observational study with 6 months CGM data.	With 6 months Loop use; TIR Mean glucose HbA1c TBR	(vs baseline) 73 vs 67% 147 vs 155 mg/dL 6.5 vs 6.8% 2.8 vs 2.9%
Petruzelkova (2021)	Czech Republic (33576551)	AndroidAPS (Retrospective cohort)	36 children; 18 pre-school (age 3-7 years), 18 school age (age 8-14) who had switched from SAP to AndroidAPS.	After 6 months AndroidAPS; HbA1c TIR 3-3.8mmol/L	(pre-school vs SAP and school age children vs SAP) 48.5 vs 53.8mmol/mol and 45.1 vs 52.6mmol/mol 78.6 vs 70.8% and 82.9 vs 77.2% 3.0 vs 3.0% and 3.8 vs 2.6%
Gawrecki (2021)	Poland (33819289)	AndroidAPS (Prospective cohort)	12 subjects; 5 men, 7 women, mean age 31.3 years, duration of diabetes 16.1 years, HbA1c 6.8%/51.3	After 12 weeks AndroidAPS; TBR TIR <70mg/dL HbA1c	(vs baseline) 0.35 vs 0.25% 79.3 vs 68% 1.75 vs 2.50% 6.3 vs 6.8%

			mmol/mol on CSII at baseline, after 3-week run-in period, 12 weeks of AndroidAPS use.	Insulin requirement Body weight Safety	0.60 vs 0.62 units/kg 71.3 vs 70.5kg No SH /DKA with AndroidAPS
Jeyaventhan (2021)	UK (33999488)	Loop, AndroidAPS, OpenAPS vs Medtronic 670G (Retrospective cohort)	68 participants; 38 Medtronic 670G, 30 DIY (50% Loop, 36.7% AndroidAPS, 13.3% OpenAPS). 6 months of glycemic data reviewed with respective systems.	Change with 6 months DIY; HbA1c TIR Mean glucose TAR TBR Safety	(vs 6 months Medtronic 670G use) -0.9 vs -0.1% 78.5 vs 68.2% 7.6 vs 8.9 mmol/L 18.4 vs 29.2% 3.2 vs 2.6% A non-significant increase SH with 670G, no DKA
March (2021)	USA (33900843)	OpenAPS AndroidAPS Loop (Cross-sectional)	104 school nurses, completed online survey of current practices, knowledge and beliefs surrounding DIY AID; 99% female, mean age 47.9 years.	Have a student using DIY AID at their school. No prior knowledge of DIY AID Children should be able to use DIY AID in school. School nurse should be responsible for DIY system if child not independent. Students should be able to share CGM data with parent/guardian. Open-ended question response themes.	23% 46% 82% 33% 96% Guidance and defined expectations, reactions to fears and the unknown, adopt and adapt.
Braune (2021)	Germany with virtual respondents from 35 countries (34096874)	OpenAPS AndroidAPS Loop (Cross-sectional)	897 participants; 722 adults with T1DM, 175 caregivers of children with T1DM. Web-based cross-sectional survey (DIWHY)	Motivations to commence OpenAPS for Adult users	(vs caregivers) Improve glycemic control 93.5% vs 95% Reduce acute complications 97.2% vs 96% Reduce LT complications 83.3% vs 91% Less freq. tech interaction 81.1% vs 86% Improved sleep quality 71.6% vs 80% Increased life expectancy 75.1% vs 84% Lack of Commercial AID 70.8% vs 80%

				Self-reported; HbA1c TIR	Not reaching goal with available therapy 68.4 vs 69% (vs pre-DIY AID) 6.24 vs 7.14% 80.34 vs 62.96%
Street (2021)	UK with virtual respondents (34047963)	AndroidAPS (65.6%), Loop (30.4%) and OpenAPS (3.2%) (Cross-sectional)	296 participants (253 from UK) in an online survey distributed via Twitter and Facebook groups (Looped and AndroidAPS users); 43.1% female, median age 35 years, duration diabetes 19.5 years, average duration DIY AID 10.3 months.	User demographics, type and duration of DIY AID use. TIR change with DIY AID use.	Peak ages 10-15 years and 40-45 years. Average age; Loop user 28.5 years AndroidAPS 35.8 years OpenAPS 33 years Mean increase TIR 17.3%.

Table 2.2 DIY AID Cohort Studies [4, 31-46]

First Author (Year)	Country (PMID)	AID System (Study type)	Participants	Outcomes	Results
Litchman (2019)	USA (30198751)	OpenAPS (Qualitative)	3347 tweets by 328 OpenAPS users, care givers and care partners	Twitter perceptions of OpenAPS use	1. Self-reported HbA1c and glucose variability improvement 2. Improved QOL 3. Perceived as safe 4. Provider interaction experiences 5. Customizability
Quintal (2020)	Canada (33583856)	AndroidAPS, OpenAPS, Loop (Qualitative)	Interviews with 16 participants with type 1 diabetes not using DIY AID	Views on the ethical considerations raised by DIY AID; qualitative content analysis of interview transcriptions	Subcategorized; autonomy, identity, relationships, safety, privacy, public and private coverage, justice and patient selection.
Crocket (2020)	New Zealand (31646890)	AndroidAPS, OpenAPS and Loop (Qualitative)	Semi-structured interviews with 9 mentors from the DIY APS community; 4 female, 5 male, 4 people with diabetes, 5 have family members with diabetes.	Reasons for mentoring Implementation of mentoring Challenges of mentoring	Altruism Online forums Frequency of questions, dealing with conflict and managing workload.
Litchman (2020)	USA (32627587)	AndroidAPS, OpenAPS and Loop (Qualitative)	Analysis of Twitter Data 2014-2017 looking at tweets referencing OpenAPS or WeAreNotWaiting; 46,578 tweets by 7886 participants.	Conversation sentiment. Visual representations of patient-led innovation. Identification of personas who engage in DIY patient led technologies on twitter.	82-85% positive interactions Photos disseminate media and conference coverage, showcase devices, celebrate connections and accomplishment and provide instructions. Personas are; fearless leaders, loopers living it up, parents on a mission, the tech titans, movement supporters and HCP advocates.

Shepard (2020)	USA (33000636)	AndroidAPS, OpenAPS, Loop (Qualitative)	Summary of a workshop with 60 stakeholders at Advanced Technologies and Treatment in Diabetes Conference Feb 2020.	User perspectives HCP perspectives Ethical considerations	No increase safety risk relative to human error. Value HCP willingness to learn about DIY AID. Limited knowledge and experience, liability and safety concerns. Off-label devices, alterations in patient-clinician relationship.
Schipp (2021)	Australia (33720767)	AndroidAPS, OpenAPS and Loop (Qualitative)	Semi-structured interview with 23 adults with T1DM using DIYAID for 1-34months, age 25-64 years, 10 female, 13 male.	Participants reported challenges with DIY AID. Participants reported support strategies.	Financial cost set-up, sourcing hardware, lack of technical knowledge, time consuming set-up, potential risks, lack of support from industry, lack of familiarity HCPs with technology, carrying multiple components, battery use, screen time. Peer support, self-sufficiency, risk management and trade-offs.
Crocket (2021)	New Zealand (34826158)	AndroidAPS (Qualitative)	Community Derived Automated Insulin Delivery study (CREATE); content analysis from fortnightly team meetings in the first 4 months of the trial. Team comprised; 5 endocrinologists, 5 diabetes specialist nurses, 2 open-source AID community members.	Key topics discussed; from review of meetings and Slack digital communication platform	AID user-interface was the most frequently reported AID specific challenge for HCP. Challenges largely related to specific devices, rather than AID. Most frequent learning challenge was insulin pump and cannula problems relating to DANA-I insulin pump (24 % of conversations)
Schipp (2021)	Australia (34599617)	AndroidAPS, OpenAPS and Loop (Qualitative)	Semi-structured interview; 23 adults T1D using DIY; 25-64 years, 10 F. Using DIY AID; <6 months (n=9), 6-12 months (n=6) or > 12 months (n=8).	Participants key features they value in DIY AID. Benefits of these features Perspectives on future use of these systems.	Compatibility, user-led design, customizability, ability to evolve faster and community driven. Choice, solutions which meet needs, ownership, staying one-step ahead and real-time support. Collaboration with commercial products, to enable them to benefit from open-source learning.

Wong (2021)	USA (34780283)	Loop (Mixed-Methods)	46 of 874 Loop users identified as discontinuing during the observation time period. 45 completed a discontinued use survey and 19 semi-structured interviews.	Factors associated with discontinued use. Reasons for stopping. Prominent themes on qualitative analysis.	Older age and not trusting Loop. 'I decided to try something else' - 27.8% 'It just didn't help as much as I thought it would' – 22.2% Mental and emotional burden, adjusting settings, fear of disapproval, technical and logistical barriers, specific circumstances and concerns.

Table 2.3 DIY AID Qualitative Studies [47-55]

Chapter 3: Canadian Healthcare Providers' Attitudes Towards Automated Insulin Delivery Systems

3.1 Introduction

Automated Insulin Delivery (AID) or closed-loop systems combine an insulin pump with continuous subcutaneous insulin infusion (CSII), and a Continuous Glucose Monitor (CGM), controlled by a computerized predictive algorithm. This enables automated adjustment in insulin delivery rate based on CGM data. These systems are termed 'hybrid closed-loop' due to the integration of this automated, algorithm mediated insulin delivery, with additional user input, such as mealtime insulin boluses [1]. Commercial AID systems are associated with improved glycemic outcomes and are the most technologically advanced, regulatory approved method of insulin delivery [2].

In Canada, Commercial AID was first introduced in 2018 and three systems are currently available; Medtronic 670G and 770G (combining a Medtronic pump and Guardian 3 sensor) and Tandem Control-IQ (combining Tandem t:slim X2 pump and Dexcom G6 sensor) [3]. Despite some clear beneficial outcomes, notably in glycemia, quality of life and safety, these systems are felt to be suboptimal by many people with type 1 diabetes. The systems are expensive, development and incorporation of new features is a slow process, glucose targets lack flexibility, and therefore these systems do not meet the lifestyle needs of many users. In contrast, novel, unregulated and unapproved, user-designed or do-it-yourself (DIY) AID systems are increasingly being used. These systems which were developed prior to the introduction of any Commercial AID systems, are categorized according to the algorithm and technology which they incorporate into; OpenAPS, AndroidAPS and Loop systems. Users build their own DIY AID system with the help of online instructions and support from other users via social-media platforms [4].

The user-built and unregulated nature of DIY AID systems makes them a challenging prospect for healthcare providers (HCP) caring for people with type 1 diabetes that are currently using or contemplating commencing use of one of these systems.

Approved technologies (CSII and CGM), prescribed by HCP, are effectively being 'hacked' and implemented in an unregulated and unapproved way by the user [5]. There has been no official guidance for HCP in Canada as to how they should address patients who are using, or planning to use a DIY AID system.

HCP opinions and current practices towards DIY AID use have previously been collected in studies in both the United Kingdom (UK) [6] and United states of America (USA) [7,8]. The UK study, used an online questionnaire to survey the opinions of 317 HCP (46% consultants and 8% registrars/trainees in Diabetes and Endocrinology, 38% diabetes specialist nurses or dieticians and 8% other HCP). One cross-sectional study from the USA, used a paper-based survey to collect opinions from 47 HCP (90.7% female), in addition to an online survey, evaluating usefulness and acceptability of an AID education and a comparison factsheet, with 137 responses (93% female), 91% of these respondents were diabetes nurses and nutritionists [7]. A second study from the USA reported an American Association of Diabetes Educators HCP survey with 152 respondents, of these 27% reported that they felt DIY AID systems were safe [8], with just 2% of the UK HCP respondents perceiving DIY AID as dangerous [6].

We performed a cross-sectional to study to assess current HCP knowledge, experience and attitudes towards AID across Canada. We aimed to highlight prevalent areas of knowledge gaps and consistent patterns in HCP concerns in order to direct future targeted HCP education and consensus guidelines, to ultimately ensure that users of AID systems receive consistent and appropriate patient care.

3.2 Methods

A 31-item anonymized online survey was designed, the development process involved both assessment of face validity from HCP, as well as perspectives from patient-researchers active in the DIY community. The final version of this survey (appendices figure 3.1.1) was estimated to take approximately twenty minutes to complete, and was distributed using the REDCap (Research Electronic Data Capture) system. REDCap is a secure, web-based software platform, designed to support data capture for research studies [9,10]. Participants were HCP licensed to practice in Canada, looking

after children and/or adults with type 1 diabetes. The survey comprised sections relating to; HCP and practice characteristics, HCP current experience and attitudes towards AID, perceived barriers to AID use, comfort levels with AID use in specific patient scenarios and potential enablers of AID. Participants were asked to answer all questions, with the option of not applicable (n/a), unsure, or prefer not to say always available. An additional six questions relating to specifics of DIY AID system settings and applications used in conjunction with DIY AID systems, were asked to respondents that deemed themselves to be 'actively involved' in the care of people using DIY AID systems.

The study was approved by the University of Alberta Research Ethics Board, study ID Pro00108472. A snowball sampling strategy was employed. An electronic link to the survey was sent to prospective participants through their place of work, diabetes specialist networks in Canada and additionally distributed via social media platforms. Participant responses were anonymous, with no directly identifiable information in responses, the only potentially identifiable data related to province and setting of practice (whether rural or urban, and in a community or academic centre).

Descriptive statistical analysis, Spearman correlation coefficient, paired Wilcoxon signed rank test (with comparison of HCP responses relating to the two system types) and Kruskal-Wallis test with Dunn's multiple comparison test (for subdivision of responses according to HCP type), were performed using GraphPad Prism version 9.2.0 for macOS; GraphPad software, San Diego, California, www.graphpad.com. The level of statistical significance was defined as a p value <0.05. NVivo 12 QSR; Melbourne, Australia, www.qsrinternational.com, was utilized to identify the dominant issues in the HCP qualitative responses, through word count and word cloud analysis [11].

3.3 Results

3.3.1 HCP and Practice Characteristics

In total, n=204 responses were collected with the online survey open for 35 days; June 25th until July 30th 2021. HCP practice characteristics are shown in table 3.1. The most

prominent locations for respondents were Ontario 75 (36.8%), Alberta 65 (31.9%), Quebec 18 (8.8%) and British Columbia 17 (8.3%) in Community Urban 84 (41.2%), Academic Centres 58 (28.4%) and Urban Hospitals 33 (16.1%). The majority of respondents 104 (51%) care for adults with type 1 diabetes, with 47 (23%) children and 53 (26%) both, with 112 (54.9%) designated Certified Diabetes Educators (CDE).

Respondents were HCP with a variety of practitioner roles; 67 (32.8%) registered dieticians (RD), 65 (31.9%) registered nurses (RN), 58 (28.4%) MD Endocrinologists and 7 (3.5%) MD in other specialties. The majority of practitioners had been working with people with type 1 diabetes for more than six years; 6-10 years, 57 (27.9%), 11-20 years 47 (23%) or greater than 20 years 49 (24%), largely as part of a diabetes clinic or program, 178 (87.3%).

Table 3.1 Healthcare Provider Characteristics and Technology Experience of Survey Respondents

Demographic		Respondents n (%), total=204
Location		
	British Columbia	17 (8.5)
	Territories	1 (0.5)
	Alberta	65 (31.9)
	Saskatchewan	7 (3.4)
	Manitoba	12 (5.9)
	Ontario	75 (36.8)
	Quebec	18 (8.8)
	Maritimes	8 (3.9)
	Prefer not to say	1 (0.5)
Practice Setting		
	Academic Centre	58 (28.4)
	Urban Hospital	33 (16.2)
	Rural Hospital	7 (3.4)
	Community- Urban	84 (41.2)
	Community- Rural	18 (8.8)
	Prefer not to say	4 (2)
Patient group		
	Adults	104 (51)
	Children	47 (23)

	Both	53 (26)
Designated CDE		
	Yes	112 (54.9)
	No	90 (44.1)
	Prefer not to say	2 (1)
Practitioner type		
	MD Endocrinology	58 (28.4)
	MD Internal Medicine	1 (0.5)
	MD Family Medicine	1 (0.5)
	MD other	5 (2.5)
	RN	65 (31.9)
	RD	67 (32.8)
	Pharmacist	5 (2.5)
	Prefer not to say	2 (1)
Length of practice (years)		
	<1	5 (2.5)
	1-5	46 (22.5)
	6-10	57 (27.9)
	11-20	47 (23)
	>20	49 (24)
Practice type		
	Individual	24 (11.7)
	Clinic/Program	178 (87.3)
	Prefer not to say	2 (1)
Number of patients with T1DM		
	<10	12 (5.9)
	10-50	49 (24.0)
	51-100	32 (15.7)
	100-500	60 (29.4)
	>500	39 (19.2)
	Unsure	12 (5.9)
Proportion of patients using CSII (%)		
	<5	25 (12.3)
	5-24	38 (18.6)
	25-49	72 (35.3)
	50-75	42 (20.6)
	>75	15 (7.4)
	Unsure	12 (5.9)
Proportion of patients using sensors (%)		
	<5	6 (2.9)
	5-24	22 (10.8)
	25-49	53 (26.0)
	50-75	88 (43.1)
	>75	29 (14.2)
	Unsure	6 (2.9)

Number of patients using Commercial AID		
	None	17 (8.3)
	1-5	29 (14.2)
	6-24	57 (27.9)
	25-50	39 (19.1)
	51-100	19 (9.3)
	>100	13 (6.4)
	Unsure	30 (14.7)
Number of patients using DIY AID		
	None	46 (22.5)
	1-5	77 (37.7)
	6-14	26 (12.7)
	15-24	17 (8.3)
	25-50	4 (2.0)
	>50	1 (0.5)
	Unsure	33 (16.2)

3.3.2 Current experience and attitudes towards AID

The majority of respondents felt very comfortable in supporting their patients with both CSII (116, 56.9%) and glucose sensor (real time or intermittently scanned CGM) use (150, 73.5%). While most HCP reported feeling comfortable supporting Commercial AID 141 (72.7%), only a minority 42 (21.6%) felt the same for DIY AID, the most frequent response being that participants were not at all comfortable supporting the use of DIY AID systems (64, 33%), figure 3.1. Comfort levels subdivided according to HCP role (MD Endocrinology, RN, RD and other; comprising other MDs, pharmacists and prefer not to say), specifically towards Commercial and DIY AID systems are shown in figure 3.2 and table 3.2. There was no significant difference in technology comfort according to HCP role; CSII kw=3.162, p=0.333, Sensors kw=0.250, p=>0.999, Commercial AID kw=2.279, p=0.467 and DIY AID kw=4.848, p=0.067, although greatest comfort with DIY AID was expressed by RN.

Figure 3.1 Healthcare Provider current comfort levels in supporting technology use

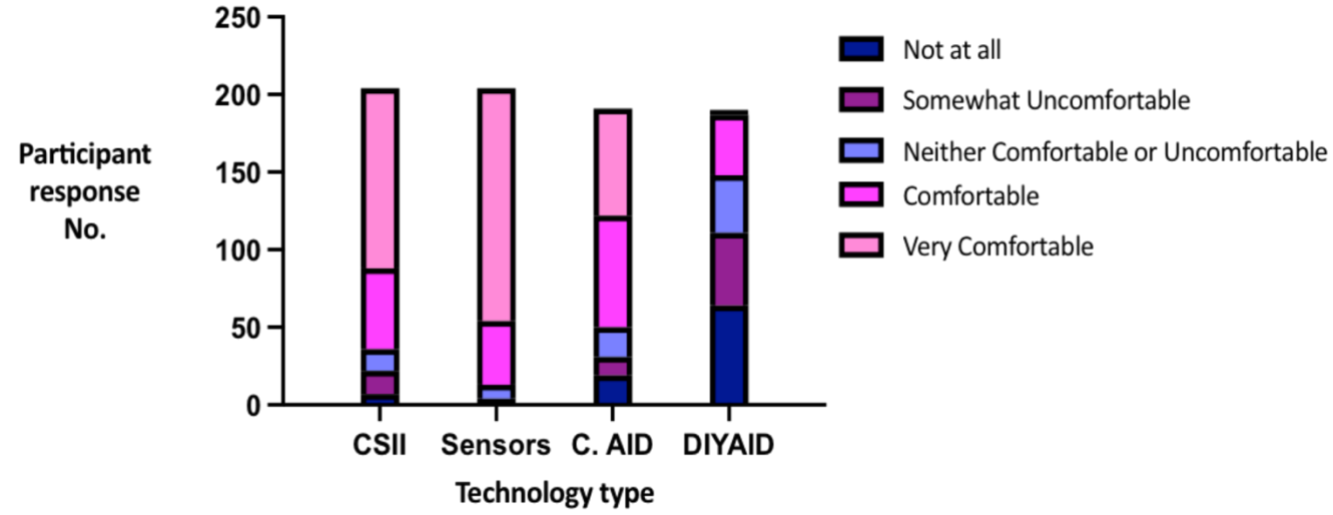


Figure 3.2. Comfort levels with Commercial and DIY AID systems subdivided according to Healthcare Provider role

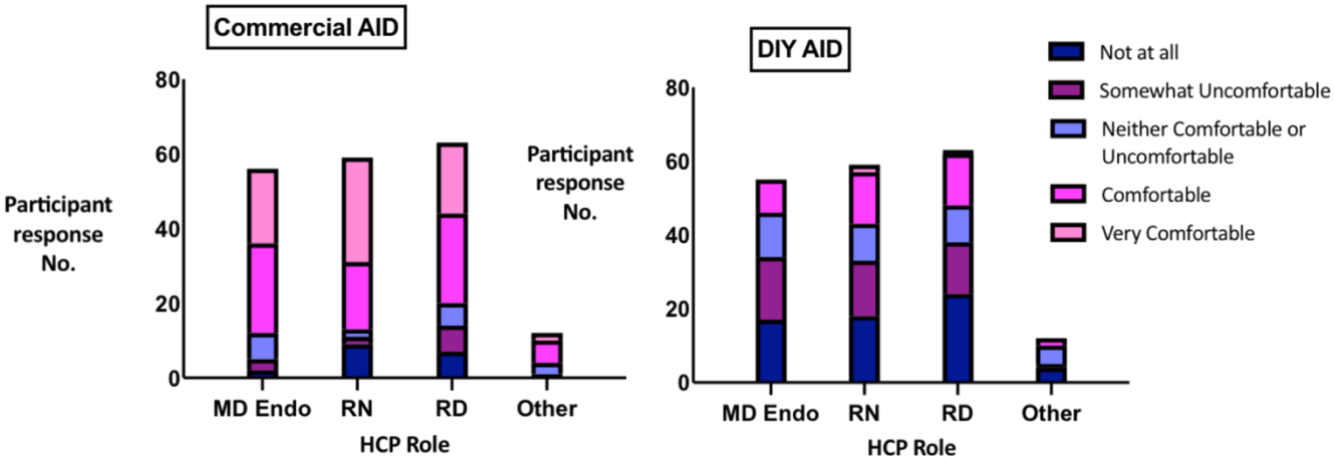


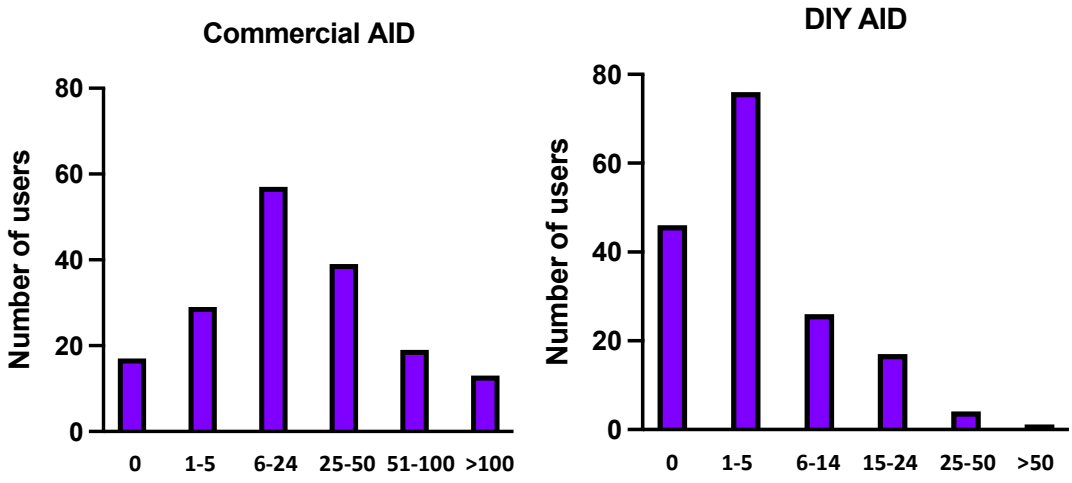
Table 3.2 Technology comfort in different Healthcare Provider roles

Technology type and comfort level	MD Endo	RN	RD	Other	*p value
CSII					
Not at all	1 (1.7)	3 (4.6)	2 (3.0)	1 (7.7)	
Somewhat Uncomfortable	0 (0)	8 (12.3)	7 (10.4)	0 (0)	p= 0.33
Neither	4 (6.9)	1 (1.5)	7 (10.4)	1 (7.7)	
Comfortable	19 (32.8)	7 (10.8)	20 (29.9)	6 (46.2)	
Very Comfortable	34 (58.6)	46 (70.8)	31 (46.3)	5 (38.5)	
Sensor					
Not at all	0 (0)	0 (0)	0 (0)	0 (0)	
Somewhat Uncomfortable	1 (1.7)	0 (0)	3 (4.4)	0 (0)	p= >0.99
Neither	2 (3.4)	4 (6.0)	3 (4.4)	1 (1.7)	
Comfortable	13 (22.4)	13 (19.7)	13 (19.4)	2 (15.4)	
Very Comfortable	42 (72.4)	49 (74.2)	48 (71.6)	10 (76.9)	
Commercial AID					
Not at all	2 (3.6)	9 (15.3)	7 (11.1)	1 (8.3)	
Somewhat Uncomfortable	3 (5.4)	2 (3.4)	7 (11.1)	0 (0)	p= 0.47
Neither	7 (12.5)	2 (3.4)	6 (9.5)	3 (25.0)	
Comfortable	24 (42.9)	18 (30.5)	24 (38.1)	6 (50.0)	
Very Comfortable	20 (35.7)	28 (47.5)	19 (30.2)	2 (16.7)	
DIY AID					
Not at all	17 (30.9)	18 (30.5)	24 (38.1)	4 (33.3)	
Somewhat Uncomfortable	17 (30.9)	15 (25.4)	14 (22.2)	1 (8.3)	p= 0.07
Neither	12 (21.8)	10 (16.9)	10 (15.9)	5 (41.7)	
Comfortable	9 (16.4)	14 (23.7)	14 (22.2)	2 (16.7)	
Very Comfortable	0 (0)	2 (3.4)	1 (1.6)	0 (0)	

* Kruskal-Wallis analysis comparing Healthcare Provider ranking of comfort with technology type, according to Healthcare Provider role.
Data are presented as n (%)

The median practice size was 100-500 patients with T1D, with median 25-49% CSII users, 50-75% using sensors, 6-24 patients Commercial and 1-5 patients DIY AID (figure 3.3). A moderate but significant association was seen between reported comfort levels and proportion of patients in HCP practice using CSII ($r=0.5234$, $p<0.0001$), sensors ($r=0.2997$, $p<0.0001$), Commercial ($r=0.5675$, $p<0.0001$) and DIY AID ($r=0.4532$, $p<0.0001$). The number of respondents that expressed feeling comfortable with technologies was greatest for glucose sensors, followed by CSII, and Commercial with least comfort for DIY AID. There was a significant difference in comfort dependent upon device type; $kw=9.231$, $p=0.02$, and post hoc analysis revealed this mean rank difference to be greatest between Sensors and DIY AID ($p=0.02$).

Figure 3.3 Number of Commercial and DIY AID system users



With reference to DIY AID systems, HCP most frequently reported that they never initiated discussions with their patients about these systems (94, 48.5%), this was despite 87 (44.8%) of respondents describing themselves as being slightly or much more supportive of DIY AID technology than other diabetes professionals and 106 (60.2%), of respondents advised they would probably or definitely support a patient or family member's decision to start using a DIY system (table 3.3).

Table 3.3 DIY AID current practice dependent on Healthcare Provider role

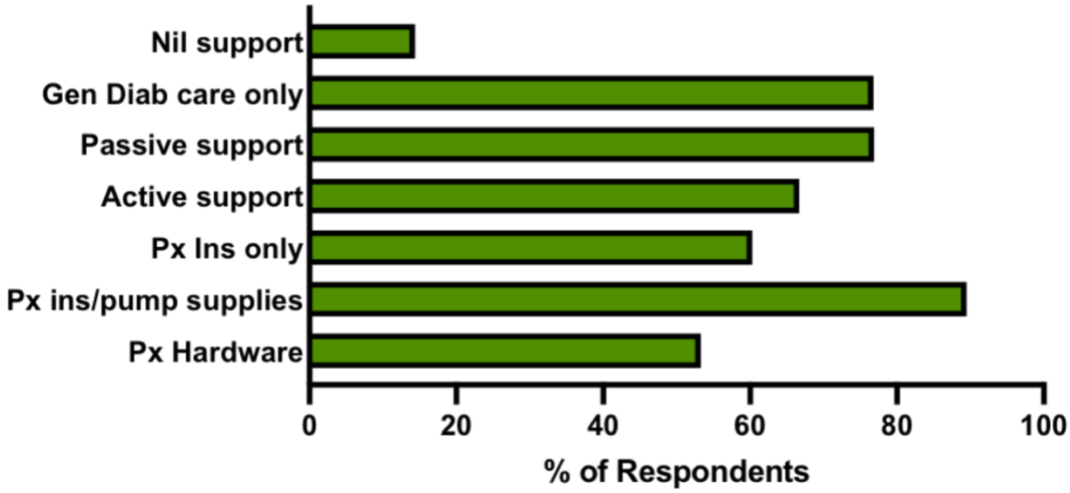
Situation	MD Endo	RN	RD	Other	*p value
Initiate discussion					
Never	27 (48.2)	29 (49.2)	30 (48.4)	7 (58.3)	
Rarely	16 (28.6)	16 (27.1)	15 (24.2)	2 (16.7)	p=0.95
Sometimes	8 (14.3)	13 (22.0)	13 (21.0)	3 (25.0)	
Frequently	3 (5.4)	1 (1.7)	3 (4.8)	0 (0)	
Always	2 (3.6)	0 (0)	1 (1.6)	0 (0)	
Relative to other HCP					
Much less	3 (5.4)	4 (6.6)	7 (10.9)	0 (0)	
Slightly less	4 (7.1)	5 (8.2)	3 (4.7)	1 (8.3)	
Same	23 (41.1)	17 (27.9)	16 (25.0)	6 (50.0)	p= 0.56
Slightly more	12 (21.4)	15 (24.6)	20 (31.3)	1 (8.3)	
Much more	10 (17.9)	16 (26.2)	12 (18.8)	1 (8.3)	
Unsure	4 (7.1)	4 (6.6)	6 (9.4)	3 (25.0)	
Support DIY start					
Definitely not	1 (1.9)	3 (5.4)	1 (1.8)	0 (0)	
Probably not	9 (17.0)	5 (8.9)	3 (5.3)	3 (33.3)	p= 0.03
Neither	13 (24.5)	18 (32.1)	12 (21.1)	2 (22.2)	
Probably yes	25 (47.2)	15 (26.8)	22 (38.6)	3 (33.3)	
Definitely yes	5 (9.4)	15 (26.8)	19 (33.3)	1 (11.1)	

* Kruskal-Wallis analysis comparing Healthcare Provider ranking of response to situations, according to Healthcare Provider role.

Data are presented as n (%).

If a patient had started using a DIY system the respondents were asked which aspects of care, they would be willing to provide (figure 3.4), with 22 (14.4%) advising they would not provide ongoing support, referring their patient to another diabetes clinic/provider.

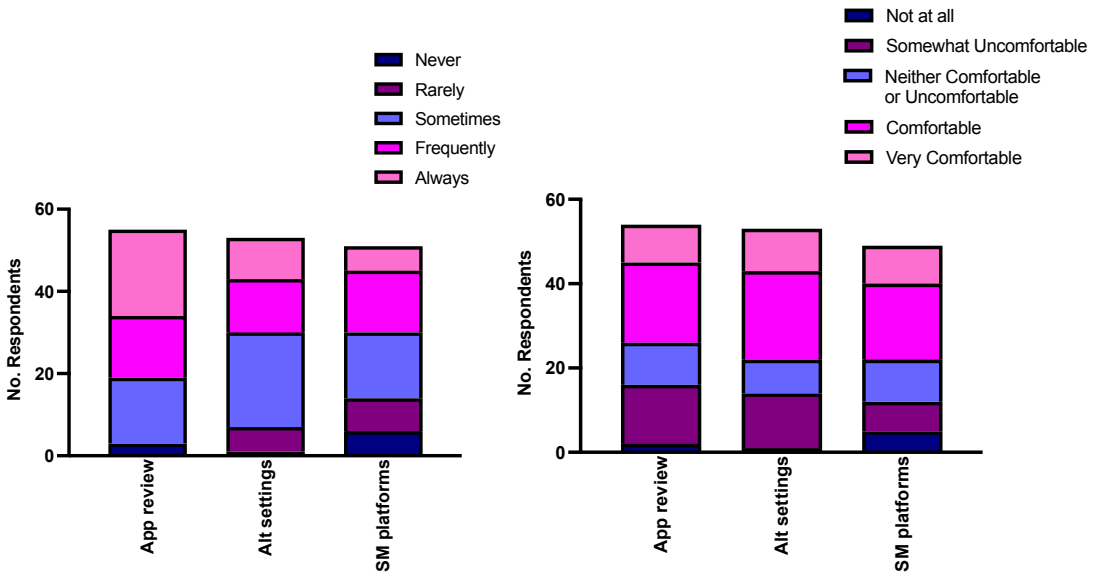
Figure 3.4. Aspects of care relating to DIY systems that Healthcare Providers are willing to provide



3.3.3 Active involvement in DIY AID

Of the 164 participants who responded to this question, 55 (33.5%) stated that they felt themselves to be actively involved in the care of patient's using DIY systems, these individuals comprised 17 MD Endocrinologists, 24 RN, 12 RD and 2 other HCP (MD other and a pharmacist). These HCP were then asked about the extent of their involvement in reviewing DIY system specific applications, making alterations in settings and discussion of relevant social media platform interactions, in terms of both frequency and comfort (figure 3.5).

Figure 3.5 Healthcare Providers deeming themselves to be actively involved in DIY AID *



3.3.4 Barriers to AID use

The perceived barriers which HCP agreed were preventing AID system use are shown in table 3.4. Funding/coverage for technology was felt to be a barrier in both Commercial; 102(55%) insulin pumps, 151 (81.6%) glucose sensors, and DIY AID systems; 94 (53.1%) insulin pumps, 135 (76.3%) glucose sensors. The greatest perceived barriers to DIY system use were a lack of approved device options (148, 83.6%) and access to staff with system training, 151 (85.3%). Comparison of potential barriers between Commercial and DIY AID systems, revealed a significantly higher number of respondents deemed overall barriers towards DIY relative to Commercial AID (p= 0.001). All proposed barriers were ranked significantly greater for DIY systems relative to Commercial, except funding/coverage for pumps which were equivalent.

* For HCP who deemed themselves to be actively involved in DIY AID use, this graph details response to questions relating to both frequency and comfort with:

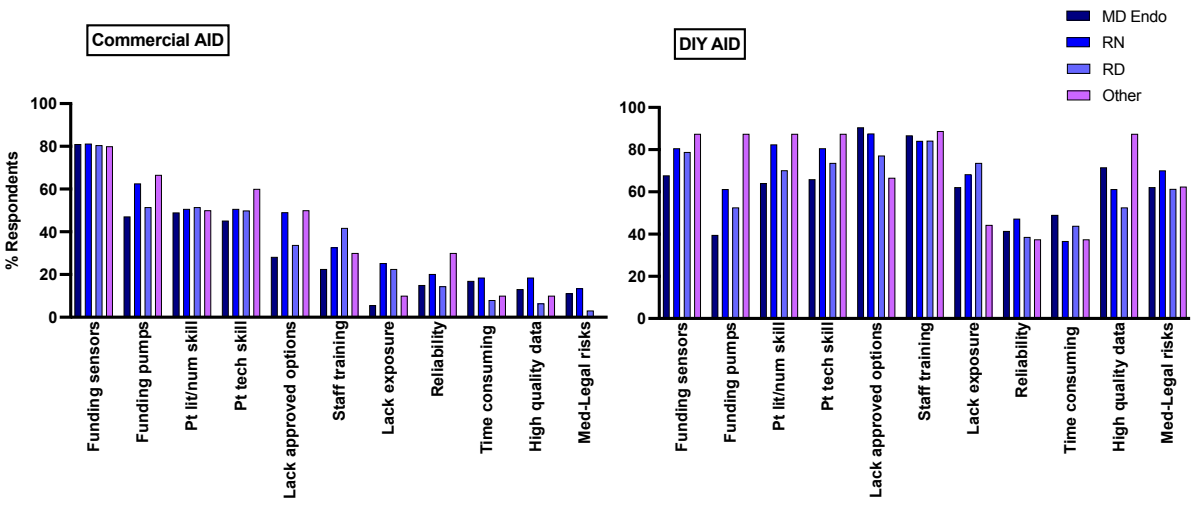
- App review; HCP review of glucose data through DIY AID specific application eg. Nightscout, Tidepool.
- Alt settings; HCP suggesting alteration in DIY AID system settings
- SM platforms; HCP discussing with users any specific social media support platforms they are using relating to DIY AID use.

Table 3.4 Potential barriers towards AID systems

Potential barrier	Commercial AID	DIY AID	* p value
Funding/coverage for sensors	151 (81.6)	135 (76.3)	p=0.0004
Funding/coverage for pumps	102 (55.1)	94 (53.1)	p=0.8715
Patient literacy and numeracy	94 (50.8)	128 (72.3)	p<0.0001
Patient technological skill	91 (49.2)	130 (73.4)	p<0.0001
Few options for officially approved devices	73 (39.5)	148 (83.6)	p<0.0001
Lack of access to staff with system training	60 (32.4)	151 (85.3)	p<0.0001
Unfamiliar/lack exposure	33 (17.8)	130 (73.4)	p<0.0001
Reliability of the system	32 (17.3)	74 (41.8)	p<0.0001
Too time consuming	27 (14.6)	75 (42.4)	p<0.0001
Lack of high-quality published data	23 (12.4)	110 (62.1)	p<0.0001
Medico-legal risks	18 (9.7)	114 (64.4)	p<0.0001

These perceived barriers to AID use were not significantly different dependent on HCP role (figure 3.6).

Figure 3.6 Healthcare Provider perceived barriers to the use of Commercial and DIY AID systems according to Healthcare Provider role



* Wilcoxon Signed Rank of perceived barrier; comparing responses for perception of these barriers between Commercial and DIY AID systems. Data are presented as n (%)

HCP were asked about characteristics they felt were important for determining suitability of AID (figure 3.7 and table 3.5); the most prominent factor identified both for DIY AID systems and Commercial AID was educational level/cognitive ability (155, 91.2% and 152, 89.4% respectively). For all suggested factors, respondents were more likely to deem patients suitable for Commercial AID relative to DIY systems (p=0.004).

Figure 3.7 Characteristics deemed to be important by all Healthcare Providers in determining suitability for AID

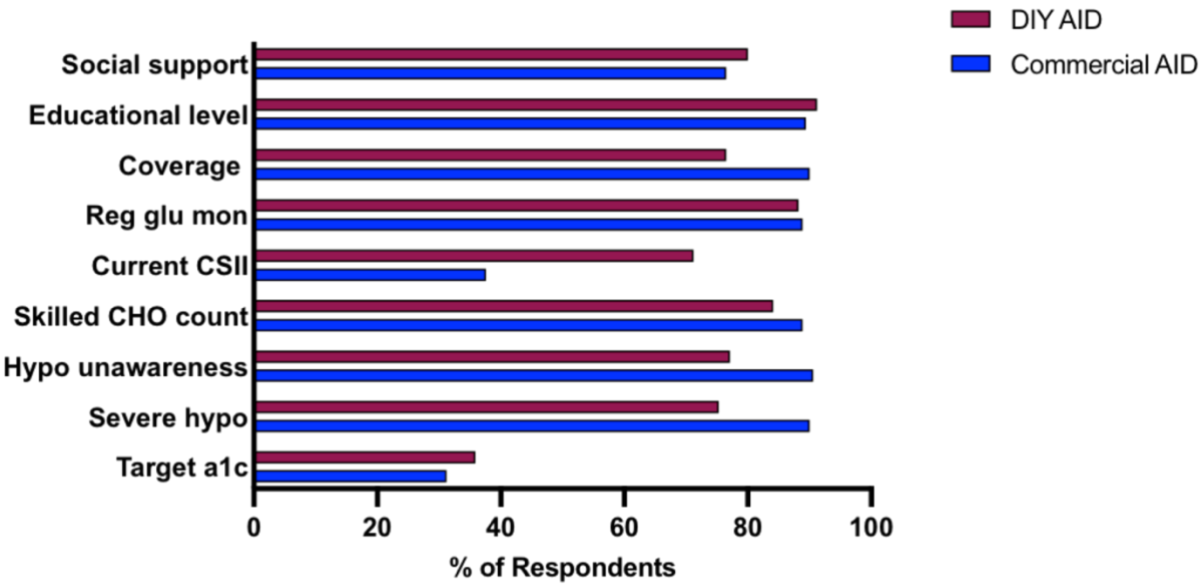


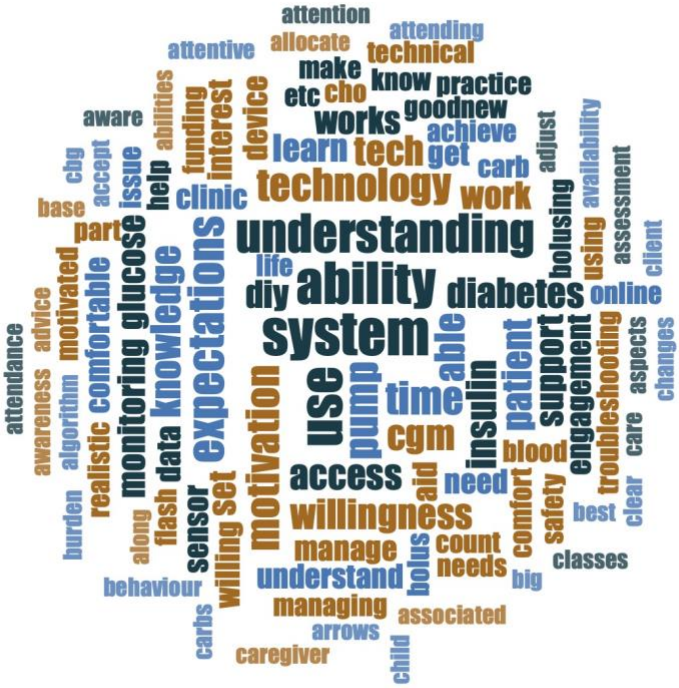
Table 3.5 Characteristics important in determining suitability for AID according to Healthcare Provider role

Characteristic	MD Endo, n (%)		RN, n (%)		RD, n (%)		Other, n (%)	
	C AID	DIY	C AID	DIY	C AID	DIY	C AID	DIY
HbA1c at/close to target								
Not at all	12(23.5)	4(8.2)	11(21.2)	8(13.3)	14(25.0)	11(19.6)	2(22.2)	1(14.3)
Not very	22(43.1)	16(32.7)	19(36.5)	15(25.0)	27(48.2)	22(39.3)	4(44.4)	2(28.6)
Unsure	4(7.8)	5(10.2)	1(1.9)	7(11.7)	1(1.8)	7(12.5)	0(0)	3(42.9)
Somewhat important	10(19.6)	16(32.7)	16(30.8)	11(18.3)	13(23.2)	12(21.4)	3(33.3)	1(14.3)
Very important	3(5.9)	8(16.3)	5(9.6)	19(31.7)	1(1.8)	4(7.1)	0(0)	0(0)
History Severe Hypo								
Not at all	0(0)	1(2.0)	2(3.8)	2(4.0)	2(3.6)	2(3.6)	0(0)	0(0)
Not very	3(5.8)	3(6.0)	4(7.7)	4(8.0)	4(7.1)	6(10.7)	0(0)	0(0)
Unsure	1(1.9)	3(6.0)	0(0)	2(4.0)	1(1.8)	9(16.1)	0(0)	3(42.9)
Somewhat important	23(44.2)	24(48.0)	16(30.8)	13(26.0)	21(37.5)	19(33.9)	1(11.1)	2(28.6)
Very important	25(48.1)	19(38.0)	30(57.7)	29(58.0)	28(50.0)	20(35.7)	8(88.9)	2(28.6)
Hypo unawareness								
Not at all	0(0)	1(2.0)	2(3.8)	2(4.0)	3(5.4)	2(3.6)	0(0)	0(0)
Not very	3(5.8)	3(6.0)	3(5.8)	3(6.0)	4(7.1)	6(10.7)	0(0)	0(0)
Unsure	1(1.9)	3(6.0)	0(0)	2(4.0)	0(0)	7(12.5)	0(0)	3(42.9)
Somewhat important	20(38.5)	20(40.0)	13(25.0)	12(24.0)	18(32.1)	20(35.7)	0(0)	2(28.6)
Very important	28(53.8)	23(46.0)	34(65.4)	31(62.0)	31(55.4)	21(37.5)	9(100)	2(28.6)
Skilled at CHO counting								
Not at all	0(0)	2 (3.9)	1(1.9)	0(0)	0(0)	0(0)	0(0)	0(0)
Not very	4(7.7)	3(5.9)	5(9.6)	3(6.0)	5(8.9)	2(3.6)	0(0)	0(0)
Unsure	2(3.8)	2(3.9)	1(1.9)	3(6.0)	1(1.8)	5(8.9)	0(0)	2(28.6)
Somewhat important	23(44.2)	17(33.3)	22(42.3)	18(36.0)	20(35.7)	20(35.7)	5(55.6)	3(42.9)
Very important	23(44.2)	27(52.9)	23(44.2)	26(52.0)	30(53.6)	29(51.8)	4(44.4)	2(28.6)
Current CSII use								
Not at all	6(11.5)	3(5.9)	12(23.5)	5(10.0)	17(30.4)	6(10.7)	1(11.1)	0(0)
Not very	18(34.6)	6(11.8)	17(33.3)	6(12.0)	18(32.1)	4(7.1)	2(22.2)	0(0)
Unsure	5(9.6)	3(5.9)	3(5.9)	4(8.0)	4(7.1)	4(7.1)	2(22.2)	3(42.9)
Somewhat important	12(23.1)	14(27.5)	10(19.6)	11(22.0)	12(21.4)	17(30.4)	2(22.2)	2(28.6)
Very important	11(21.2)	25(49.0)	9(17.6)	24(48.0)	5(8.9)	25(44.6)	2(22.2)	2(28.6)
Monitors glucose regularly Not at all	0(0)	1(2.0)	0(0)	1(2.0)	1(1.8)	0(0)	0(0)	0(0)
Not very	6(11.5)	2(3.9)	5(9.6)	2(4.0)	4(7.1)	1(1.8)	0(0)	0(0)
Unsure	0(0)	2(3.9)	0(0)	1(2.0)	3(5.4)	3(5.4)	0(0)	2(28.6)
Somewhat important	19(36.5)	15(29.4)	13(25.0)	10(20.0)	17(30.4)	15(26.8)	2(22.2)	3(42.9)
Very important	27(51.9)	31(60.8)	34(65.4)	36(72.0)	31(55.4)	37(66.1)	7(77.8)	2(28.6)
Coverage CSII/sensors								
Not at all	0(0)	1(2.0)	1(1.9)	0(0.0)	2(3.6)	1(1.8)	0(0)	0(0)
Not very	2(3.8)	4(8.0)	5(9.6)	4(8.0)	4(7.1)	7(12.7)	0(0)	0(0)
Unsure	0(0)	4(8.0)	1(1.9)	4(8.0)	1(1.8)	6(10.9)	0(0)	2(28.6)
Somewhat important	19(36.5)	17(34.0)	18(34.6)	19(38.0)	21(37.5)	15(27.2)	4(44.4)	1(14.3)
Very important	30(57.7)	24(48.0)	27(51.9)	23(46.0)	28(50.0)	26(47.2)	5(55.6)	4(57.1)

Education/cog. ability								
Not at all	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Not very	5(9.6)	1(2.0)	3(5.8)	1(2.0)	3(5.4)	0(0)	1(11.1)	0(0)
Unsure	3(5.8)	2(4.0)	0(0)	1(2.0)	3(5.4)	2(3.6)	0(0)	2(28.6)
Somewhat important	20(38.5)	8(16.0)	25(48.1)	15(30.0)	29(51.8)	11(19.6)	4(44.4)	2(28.6)
Very important	24(46.2)	39(78.0)	24(46.2)	33(66.0)	21(37.5)	43(76.8)	4(44.4)	3(42.9)
Family resources/support								
Not at all	0(0)	0(0)	1(1.9)	1(2.0)	0(0)	0(0)	0(0)	0(0)
Not very	9(17.3)	4(8.0)	4(7.7)	1(2.0)	5(8.9)	2(3.6)	2(22.2)	0(0)
Unsure	5(9.6)	4(8.0)	3(5.8)	3(6.0)	11(19.6)	8(14.5)	0(0)	4(57.1)
Somewhat important	21(40.4)	14(28.0)	28(53.8)	21(42.0)	29(51.8)	22(40.0)	3(33.3)	2(28.6)
Very important	17(32.7)	28(56.0)	16(30.8)	24(48.0)	11(19.6)	23(41.8)	4(44.4)	1(14.3)

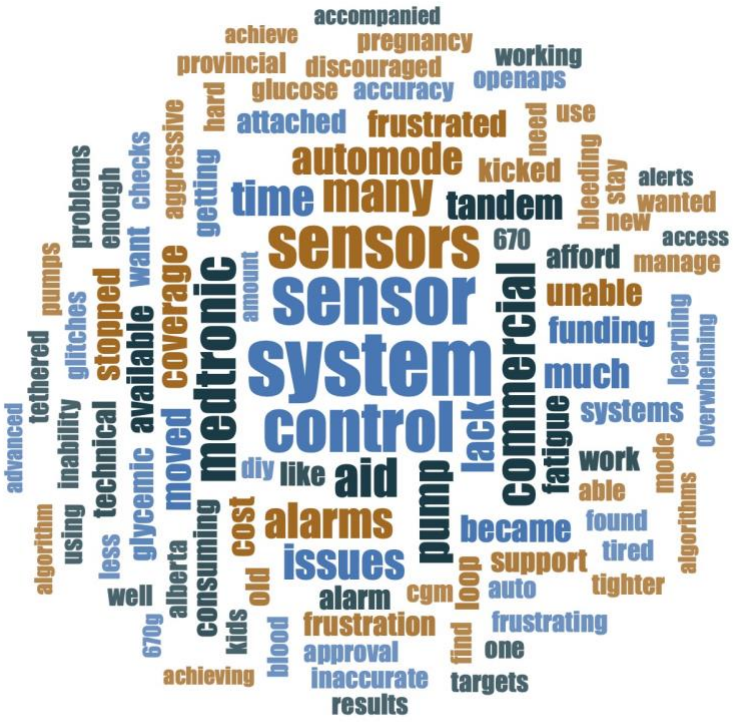
Participants were asked to note any other prerequisites they felt were essential for AID use (these are described in the word cloud in figure 3.8), with ability, understanding, expectations, motivation, technology and access the most frequent words used in response to this question.

Figure 3.8 Essential prerequisites for AID use



HCP were asked if they were aware that any of their patients had stopped using any form of AID; 79 (44.6%) answered that they were aware of someone who had stopped using an AID system. The prominent reasons for stopping AID described by HCP (figure 3.9) were sensor issues and frustration with the system and its alarms, particularly relating to the Medtronic sensor. The words 'coverage' and 'cost' appeared frequently in HCP responses to this question.

Figure 3.9 Reasons for users stopping AID

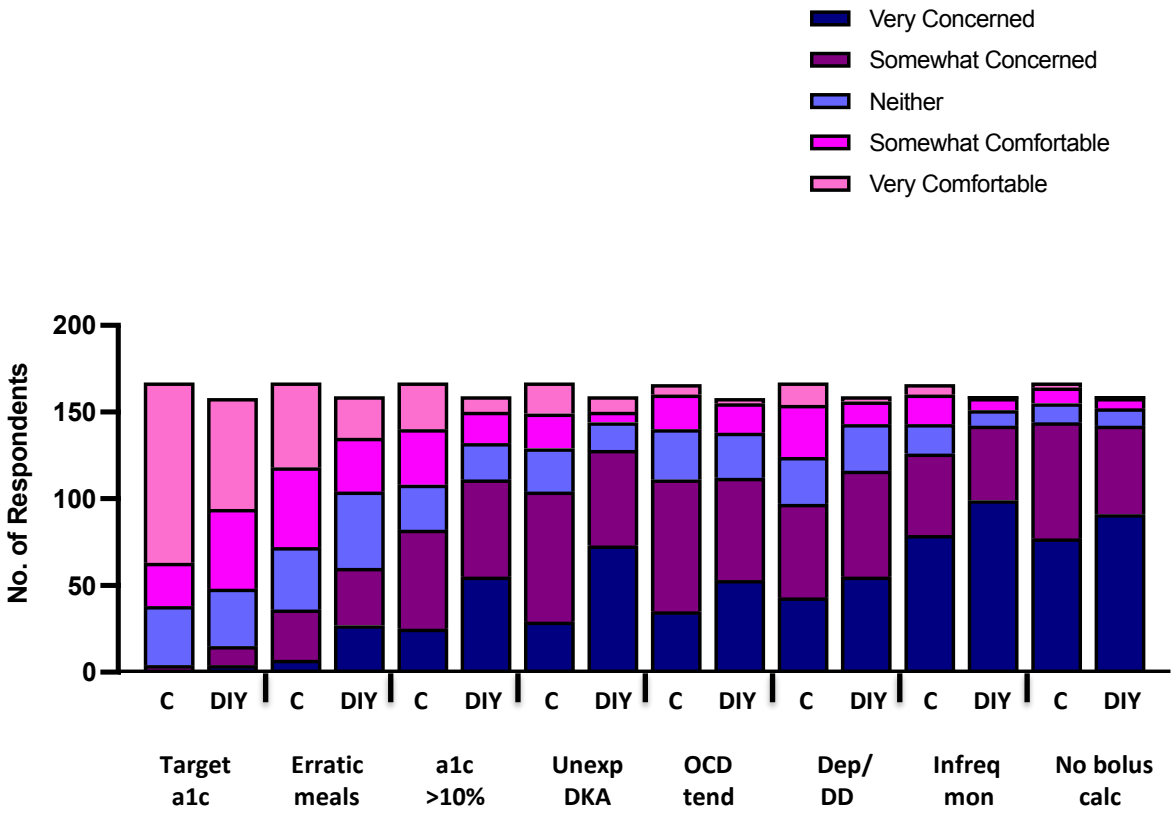


3.3.5 AID Scenarios

HCP were asked about their comfort levels with Commercial or DIY AID use in the same proposed patient scenarios (figure 3.10). In both system types the greatest level of concern was most frequently expressed by respondents in those users 'infrequently monitoring their glucose levels'; 47.3% Commercial and 60.7% DIY AID, as well as those in the scenario 'not using the bolus calculator with no set insulin:carbohydrate ratio or insulin sensitivity factor'; 46.1% Commercial and 55.8% DIY AID. Conversely,

HCP were most comfortable in the use of these systems in the setting of an individual with a 'close to target HbA1c', although comfort with Commercial systems was greater than DIY; 62.3% Commercial and 39.3% DIY AID (p= 0.001).

Figure 3.10 Healthcare Provider comfort in commencing Commercial and DIY AID systems in specific scenarios. *



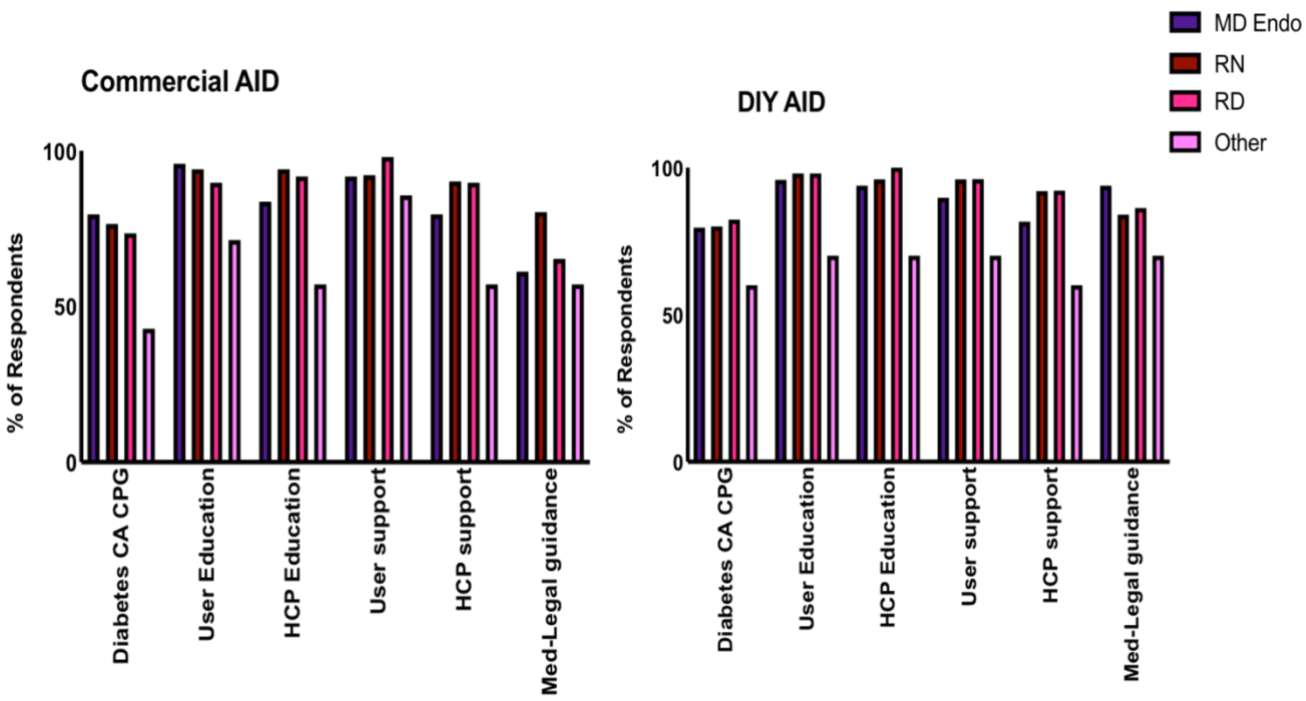
* Scenarios posed to HCP with each AID system type; An individual with at or close to target HbA1c, an individual eating erratic meals, an individual with HbA1c consistently >10%, an individual with recent unexplained DKA (in the preceding 12 months), an individual with OCD tendencies, an individual with evidence of Depression or Diabetes-related Distress, an individual who is infrequently monitoring their blood glucose levels and an individual who is not using the bolus calculator, with no set insulin:carbohydrate ratio or insulin sensitivity factor.

Comfort levels, specifically of MD Endocrinologists were reviewed for both Commercial (n=51) and DIY AID systems (n=50). With Commercial systems, this group of HCPs were very concerned with the use of these systems in those individuals 'infrequent glucose monitoring' (20, 39.2%) and 'not using bolus calculator' (21, 41.2%). Concern with DIY AID use was expressed in individuals with an 'HbA1c consistently >10%' (27, 54%) and 'an episode of unexplained DKA in the preceding 12 months' (25, 50%), in addition to 'infrequent glucose monitoring' (35, 70%) and 'not using bolus calculator' (28, 56%).

3.3.6 Potential Enablers of AID

When asked about potential interventions to improve HCP confidence in recommending either a Commercial or DIY AID system, at least two thirds of participants (113, 66%) answered positively to each suggested option. User support (147, 90.7%) and user education (145, 89.6%) were the most popular responses relating to Commercial AID, and user education (154, 95.7%) and HCP education (153, 95.1%) for DIY AID systems. MD Endocrinologists were the most frequent respondents suggesting the need for implementation of medico-legal guidance relating to DIY AID systems, 93.9% of Endocrinologists felt this was required (figure 3.11). Significantly more respondents deemed that the suggested potential interventions were required to improve HCP confidence in recommending DIY, relative to Commercial AID systems, p=0.0005. No significant difference was seen in suggested intervention according to HCP role; Commercial (KW=0.265, p=0.876) and DIY systems (KW= 0.110, p=0.946).

Figure 3.11 Potential interventions felt appropriate to improve AID confidence for different Healthcare Provider roles



3.4 Discussion

This cross-sectional study is the first to examine perspectives on the current use of AID systems (Commercial and DIY), from multidisciplinary HCP caring for adults and children with T1D from across Canada. In this survey of HCP with large type 1 diabetes clinics, with a high proportion of technology use in the form of both insulin pumps and glucose sensors, a low number of users of AID systems were reported. There were a greater number of users of Commercial relative to DIY AID, with greater HCP comfort in supporting Commercial AID use. HCP reported similar pre-requisites and cautions for safely initiating the technology with both AID types. Education, for both HCP and users, were identified as areas of intervention to increase HCP confidence in recommending AID.

Similar user numbers of DIY systems were reported by Canadian HCP to those in the 2019 UK HCP survey; 85% reported 0-5 users [12]. These figures may be imprecise, dependent on memory and recall from participants. Additionally, specifically relating to DIY AID use, HCP may not always be aware that their patients are using these systems. This may be something that a user would currently worry about disclosing to their HCP, due to concerns regarding potential technology removal or discharge from a particular clinic or provider's care [13]. Although difficult to ascertain precise figures, it is estimated that there are now over 10,000 users of DIY AID systems worldwide [14]. User survey data suggests Europe (notably Germany and the UK), North America, Australia and South Korea to be the most prominent locations, but an exact figure of the number of Canadian users of DIY AID systems is not currently available [15].

There was greater comfort with Commercial than DIY systems, although almost half of respondents deemed themselves to be more supportive of DIY systems than other HCP colleagues. Despite this, few HCP would initiate discussions relating to DIY AID and more would provide permissive support with ongoing prescription of component devices. Some HCP (14.4%), did express that they would withdraw care of patients using a DIY system, confirming patient fears of disclosing DIY AID use. Similarly, in the UK HCP survey respondents; a high proportion expressed that they would not initiate conversations with their patients about DIY AID systems (91%), but were willing to support users (55%), and most would continue to provide ongoing care (94%) [12]. The positive responses gathered relating to DIY comfort and support are not in line with the views of multi-national users of DIY AID systems; data suggests that the majority of DIY AID users, do not feel HCP in general have a good understanding of these systems [8]. With the self-selecting nature of responding to a survey, there is the potential for bias in the responses, with the prospect of this sample being from a skewed HCP population viewpoint, relating to technology experience and comfort. These user experiences may reflect diabetes care teams with less technology experience and involvement.

Cost was an important factor raised by participants resulting in restricted access to both of these systems, with insulin pumps and CGM resulting in significant financial outgoings for the user if they do not have funding or coverage for these devices. This

is estimated to be $6000-7000 CAD for an insulin pump, $3000 CAD for yearly pump supplies and $3000-$6000 CAD annually for real time Continuous Glucose Monitoring (rtCGM) [16, 17]. Although more expensive than alternate forms of insulin delivery, the use of Commercial AID is cost-effective [18]. However, as a result of provincial funding models in Canada, access remains unequal, with insulin pump use more common in areas with reimbursement programs in place [19]. DIY AID system users, in addition to an insulin pump and rtCGM, have the added costs of ensuring a suitable phone or watch interface, a communicating device or microcomputer, the subscription for a developer's license to build the relevant application as well as an appropriate computer platform to build it on [20]. Unfortunately, these described overwhelming costs to the user are likely to continue to be an ongoing barrier to the broader use of AID, unless significant changes to coverage for diabetes technologies occurs, to improve uniformity of access across Canada.

Having an at or close to target HbA1c was identified to be an optimal scenario in which to commence AID. Studies in the use of both Commercial and DIY AID systems have highlighted improvements in glycemic outcomes, demonstrated by both time in range (TIR) and HbA1c level [21, 22]. There is the potential for these systems to improve glucose control and reduce hypoglycemia [23]. Diabetes Canada recommends using Commercial AID to improve or maintain HbA1c, without increasing hypoglycemia, especially in individuals experiencing nocturnal hypoglycemia [24]. Similarly in the Diabetes UK technology pathway, Commercial AID systems are recommended in individuals with an HbA1c remaining above 8.5%, despite a single form of technology use (CSII or CGM) [25]. Our survey responses bring into question whether access to Commercial AID systems may be restricted unnecessarily, relating to an individual's current glycemic outcomes whilst using an alternative method of insulin delivery. HCP comfort may be contributing to inequitable care, further exacerbating the existing barriers to AID as a result of financial costs and coverage.

Concern was highlighted by HCP in initiating either type of AID system if an individual is infrequently monitoring their glucose levels. To their HCP this may prompt concern about lack of engagement in diabetes management and potentially treatment compliance [26]. Each of these AID system types incorporate rtCGM in combination

with an insulin pump, with rtCGM enabling automated recording of glucose levels, irrespective of frequent user input or action. Implementation of CGM use alone, without CSII or AID, is associated with improved glycemic control and a reduction in frequency of hypoglycaemia [27, 28]. While active self-management is required to mitigate risks (eg of DKA in the case of infusion set malfunction), denying access to a system that requires less user-input because of infrequent glucose monitoring appears counterintuitive.

A diagnosis of type 1 diabetes brings with it a vast amount of new information, and educational needs, often at a young age. To aid this process, structured education is key, in addition to contact with, and support from HCP, in supporting the person with diabetes with this diagnosis and its implications on their day-to-day life [25, 29]. Carbohydrate counting; to enable flexible dietary intake with optimal matched insulin delivery, the development of individual insulin to carbohydrate ratios (ICR) and insulin sensitivity factors (ISF), are crucial in optimizing glycemic outcomes, whilst utilizing multiple daily injections of insulin or traditional pump therapy [30]. HCP responding to this survey were reluctant to commence AID in the setting of 'an individual not using a bolus calculator, no set ICR or ISF'. A lack of understanding around, and implementation of, these mathematical settings, reflect a likely deficiency in diabetes-related education and crucial knowledge acquisition [31]. However, due to the nature of the algorithm incorporated in AID systems, it may be argued that this concept is less important, with the system allowing flexibility to overcome inaccuracies in carbohydrate counting. With these automated capabilities it could be considered possible for HCP themselves to program the settings, initiate and continue AID system use in a person with minimal diabetes-related education. This concept is not optimal, heavily relying upon the technology functioning as described, any system failure in this setting could result in significant harm for the user, but this may not be any greater than the risks of conventional pump failure or infusion site issues.

HCP with greater experience in the use of AID systems reported greater comfort in supporting their use. Rapid advancements, especially demonstrated in the development of user-driven DIY systems, have resulted in minimal HCP experience and low comfort levels. Unlike the Commercial systems, with no device or

pharmaceutical company at the forefront of this progression, no specific targeted education for HCP has been produced in the use of DIY systems. HCP are left in the position of noticeable knowledge gaps in the understanding of DIY AID systems, which their patients may have now implemented as their chosen glucose management system, these knowledge deficiencies were reflected in the American Association of Diabetes Educators survey [8]. There additionally remains ongoing ethical and legal uncertainty for HCP, in supporting patients who are using DIY AID systems, due to the unregulated and unapproved nature of these devices. There is a lack of consensus specialist guidance available [32]. Attitudes towards DIY AID collected were generally similar across HCP disciplines, although medico-legal concerns were most prominent among physicians.

3.5 Conclusion

The results of this survey have given a snapshot view of the current approach and practices of HCP throughout Canada, towards the use of AID systems. Limitations in AID availability due to funding or coverage of technology are apparent. These data suggest that training of providers and recommendations around best practice would be helpful for practitioners, and may also clarify medico-legal uncertainty.

Further data collection will be beneficial, including expansion of the scope of this survey to incorporate responses from more HCP, in different countries worldwide. This will enable a greater variety of experiences to be gathered, and a greater understanding of potential and beneficial interventions to be developed. The perspectives from AID system users, especially relating to their healthcare experiences, are also imperative to understand. Incorporation of user, and broader HCP knowledge and perspectives, will hopefully result in improved access to the benefits of AID use for more people with type 1 diabetes.

3.6 References

1. Leelarathna L, Choudhary P et al. Hybrid closed-loop therapy: where are we in 2021? Diabetes, Obesity and Metabolism. 2020; 23(3): 655-660.
2. Weisman A, Bai JW, Cardinez M, Kramer CK, Perkins BA. Effect of artificial pancreas systems on glycaemic control in patients with type 1 diabetes: a systematic review and meta-analysis of outpatient randomised controlled trials. Lancet Diabetes Endocrinology. 2017; 5(7): 501- 512.
3. The diaTribe Foundation. Health Canada Clears MiniMed770G Automated Insulin Delivery system, available at https://diatribe.org/health-canada-clears-minimed-770g-automated-insulin-delivery-system, last accessed 19th January 2022.
4. Jennings P and Hussain S. Do-It-Yourself Artificial Pancreas Systems: A Review of the Emerging Evidence and Insights for Healthcare Professionals. Journal of Diabetes Science and Technology. 2019; 14(5): 868-877.
5. Shaw D, Crabtree TSJ et al. The DIY Artificial Pancreas system: An Ethical Dilemma for Doctors. Diabetic Medicine. 2020; 37: 1952.
6. Crabtree TSJ, Choudhary P et al. Health-care professional opinions of DIY artificial pancreas systems in the UK. Lancet Diabetes and Endocrinology. 2020; 8(3): 186-187.
7. Murray J, Clayton M and Litchman M. Health Care Provider Knowledge and Perceptions of FDA-Approved and Do-It-Yourself Automated Insulin Delivery. Journal of diabetes science and technology. 2020; 14(6): 1017-1021.
8. Palmer W, Greely S, Letourneau-Frieburg LR, Naylor R. Using a Do-It-Yourself Artificial Pancreas: Perspectives from Patients and Diabetes Providers. Journal of Diabetes science and technology. 2020; 14(5): 860-867.
9. Harris PA, Taylor R et al. Research electronic data capture (REDCap)- A meta-data driven methodology and workflow process for providing translational research informatics support. J Biomed Inform. 2009. 42(2): 377-81.
10. Harris PA, Taylor R et al. The REDCap consortium: building an international community of software partners. J biomed Inform. 2019. May 9.

11. QSR International Pty Ltd. (2020) NVivo (released in March 2020), available at; https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home.
12. Crabtree TSJ, Choudhary P et al. Association of British Clinical Diabetologists, Diabetes Technology Network UK and Association of Children's Diabetes Clinicians Survey of UK Healthcare Professional Attitudes Towards Open-Source Automated Insulin Delivery Systems. Diabetes Therapy. 2022; e01203-5.
13. Lewis D. History and Perspective on DIY Closed Looping. Journal of Diabetes Science and Technology. 2019; 13(4): 790-793.
14. Lum J, Bailey V et al. A real-world perspective study of the safety and effectiveness of the loop open source automated insulin delivery system. Diabetes Technology and Therapeutics. 2021.
15. Braune K, Gajewska KA et al. Why #WeAreNotWaiting- Motivations and Self-Reported Outcomes Among Users of Open-source Automated Insulin Delivery Systems: Multinational Survey. J Med Internet Res. 2021; 23 (6): e25409.
16. Diabetes Canada. Coverage of Insulin pumps across Canada, March 2020, available at https://www.diabetes.ca/DiabetesCanadaWebsite/media/Advocacy-and-Policy/Advocacy%20Reports/Insulin-Pumps-Comparison-EN.pdf, last accessed 17th January 2022.
17. Diabetes Canada. Continuous Glucose Monitoring (CGM), available at https://www.diabetes.ca/DiabetesCanadaWebsite/media/Managing-My-Diabetes/Tools%20and%20Resources/Continuous_Glucose_Monitoring_Advocacy_Pkg_4.pdf?ext=.pdf, last accessed 17th January 2022.
18. Roze S, Smith-Palmer J et al. Cost-effectiveness of sensor-augmented pump therapy with low glucose suspend versus standard pump therapy in two different patient populations with type 1 diabetes in France. Diabetes Technology and Therapeutics. 2016; 18: 75-84.
19. Song C, Booth G, Perkins B and Weisman A. Impact of government-funded insulin pump programs on insulin pump use in Canada: a cross-sectional

study using the National Diabetes Repository. BMJ Open Diabetes Research&Care. 2021; 9: e002371.

20. Johnson C. Good enough? Parental decisions to use DIY looping technology to manage type 1 diabetes in children. Monash Bioethics Review. 2021; July.
21. Petrovski G, Al Khalaf F et al. One-year experience of hybrid closed-loop system in children and adolescents with type 1 diabetes previously treated with multiple daily injections: drivers to successful outcomes. Acta Diabetologica. 2021; 58(2): 207-213.
22. Lewis D and Leibrand S. Real-World Use of Open-Source Artificial Pancreas Systems. Journal of Diabetes Science and Technology. 2016; 10(6): 1411.
23. Jeyaventhan R, Gallen G, Choudhary P and Hussain S. A real-word study of user characteristics, safety and efficacy of open-loop closed-source systems and Medtronic 670G. Diabetes, Obesity and Metabolism. 2021. Online ahead of print.
24. McGibbon A, Adams L. Diabetes Canada Clinical Practice Guidelines: Glycemic Management in Adults with Type 1 diabetes. Available at http://guidelines.diabetes.ca/cpg/chapter12#bib0490, last accessed 20th January 2022.
25. Choudhary P, Campbell F, Joule N and Kar P. Diabetes UK Position Statement. A type 1 diabetes technology pathway: consensus statement for the use of technology in type 1 diabetes. Diabetic Medicine. 2019; 36(5):531-538.
26. Heiden Telo G, Schaan de Souza M et al. Comparison between adherence assessments and blood glucose monitoring measures to predict glycemic control in. adults with type 1 diabetes: a cross-sectional study. Diabetology & Metabolic Syndrome. 2016; 8(54): s13098.
27. Pickup J, Freeman S and Sutton A. Glycemic control in type 1 diabetes during real time continuous glucose monitoring compared with self-monitoring of blood glucose: meta-analysis of randomised controlled trials using individual patient data. BMJ. 2011; 343: d3805.
28. El-Laboudi A, Godsland I, Johnson D and Oliver N. Measures of glycemic variability in Type 1 diabetes and the effect of real-time continuous glucose monitoring. Diabetes Technology and Therapeutics. 2016; 18: 806-812.

29. Elliot J, Jacques RM et al. Substantial reductions in the number of diabetic ketoacidosis and severe hypoglycaemia episodes requiring emergency treatment lead to reduced costs after structured education in adults with type 1 diabetes. Diabetic Medicine. 2014; 31: 847-853.
30. Bell KJ, Barclay AW et al. Efficacy of carbohydrate counting in type 1 diabetes: a systematic review and meta-analyses. Lancet Diabetes and Endocrinology. 2014; 2(2): 133-140.
31. Sherifali D, Berard L et al. Diabetes Canada Clinical Practice Guidelines: Self-Management Education and Support. Canadian Journal of Diabetes. 2018; 42(suppl 1):s36- 41.
32. Roberts JTF, Moore V and Quigley M. Prescribing Unapproved Medical Devices? The Case of DIY Artificial Pancreas Systems. Medical Law International. 2021.

Chapter 4: Improved Glycemia and Quality of Life Among Loop users – Analysis of Real-World Data From a Single Centre

4.1 Introduction

Do-it-yourself Automated Insulin Delivery (DIY AID) systems are user-designed systems, which combine two regulated devices; an insulin pump delivering a continuous subcutaneous insulin infusion (CSII), and a Continuous Glucose Monitor (CGM), controlled by an algorithm. Through this predictive algorithm, coded by the user, these systems facilitate automated adjustment in insulin delivery, tailored to an individual's requirements [1]. People with type 1 diabetes are increasingly using these systems worldwide because the rapidly evolving software with extensive opportunities for customization helps individuals to achieve personalized glucose targets and reduce the burden of diabetes management [2].

DIY AID systems, which can be sub classified into three main systems (OpenAPS, AndroidAPS and Loop), dependent upon the technology and algorithms on which they run, have not gone through any regulatory approval processes. Users are effectively 'hacking' licensed technology in order to run these algorithms and modulate their insulin supply [3]. To date, no randomized control trials (RCT) have assessed the safety or efficacy of these systems. There are however multiple published studies; single arm cohort, user self-reported pre-post data, and case series, reporting very beneficial outcomes in glycemic control, quality of life (QOL) and reassuring safety data with DIY AID use. Studies report on individual system types or a combination of the three [4-11]. These are described in a scoping review in Chapter 2.

Studies of DIY AID system use consistently report excellent glycemic outcomes, with very high Time in Range (TIR) and low Time Below Range (TBR). These values far exceed those suggested as recommended targets, achieved by only a minority of people with type 1 diabetes [12]. Individuals choosing to use DIY AID are a select sample of people with type 1 diabetes, who are highly motivated. Users are actively involved in optimizing glycemia, with the aims of preventing diabetes-related morbidity, increasing life expectancy, as well as improving sleep quality [11].

Internet resources and social media platforms are currently the mainstay of guidance for DIY AID users [2]. These platforms have been utilized by enthusiasts in the field to collect outcome data [13]. The average age of users is reported to be 35.8 (Android APS), 33 (OpenAPS) and 28.5 years (Loop), but the extensive benefits of these systems have been reported in studies of both adults and children [10]. Similar benefits have been seen across the three DIY AID system types, with the type of system studied usually dependent upon the geographical distribution of system users. Loop is the DIY AID system most commonly used in North America and AndroidAPS in Europe [11]. To date there have been no cohort studies performed in Canada to assess DIY AID user outcomes.

We sought to explore the experiences of adults using Loop at a single centre in Canada. We aimed to assess quantitative outcomes in the form of glycemic, quality of life and safety data and also used a qualitative approach to gain a greater understanding of the lived experience of Loop users.

4.2 Method

A cross-sectional study of current glycemia, experiences and quality of life was performed in adults with type 1 diabetes, attending Kaye Edmonton Clinic (KEC) part of the University of Alberta Hospital in Edmonton AB, known to be currently using a DIY AID system. This research was approved by the University of Alberta Research Ethics Board, Study ID pro00111577.

4.2.1 Participants

Prospective participants were identified and contacted by a member of their clinical team, at KEC. All participants were adults (18 years or older) with type 1 diabetes, using a DIY AID system at the time of data collection. Following informed consent to take part in the study, a semi-structured interview with a member of the study team was arranged.

4.2.2 Outcome measures

Up to six months of most recent glucose data, whilst using Loop, was collected from the participant's CGM download data, in order to record mean TIR (3.9-10.0mmol/L),

TBR (3.0-3.9mmol/L), time <3.0mmol/L and time above range (TAR) (>10.0mmol/L). Where available, these same data were collected retrospectively from participants' glucose sensor data for the six-month period prior to commencing Loop, whilst using their previous mode of insulin delivery. Laboratory HbA1c readings (%) were collected from hospital records; the most recent value with Loop use, in addition to the participant's last reading prior to commencing Loop. Hospital records of all participants were reviewed for hospital admissions, specifically assessing occurrence of Severe Hypoglycemia (SH) and Diabetic Ketoacidosis (DKA) throughout the participants total duration of Loop use.

Semi-structured interviews were arranged via telephone or through the use of the Zoom videoconferencing service [14], between July and September 2021. A full interview transcript guide is available in the appendices figure 4.1.1. Each interview was conducted by researchers (AM and KC) with one asking the questions whilst the other transcribed responses. During the interview process demographic data was collected including; age, type of DIY AID system used, duration of DIY AID use, duration of diabetes, gender, ethnicity, occupation and highest level of educational attainment. Participants were asked to report any episodes of SH, requiring the assistance of another person to treat, and any occurrence of DKA during Loop use. Qualitative questions related to participant's reasons for commencing, challenges with its use, and support mechanisms in using a DIY AID system, as well as both the benefits and barriers they have experienced with DIY AID use.

Following the interviews participants completed two validated questionnaires electronically: the Diabetes Impact and Device Satisfaction (DIDS) [15, 16] and the Insulin Dosing Systems: Perceptions, Ideas, Reflections and Expectations (INSPIRE) [17, 18], evaluating their perceived impact of using DIY AID, on their QOL. Full copies of these questionnaires are available in the appendices figure 4.1.3 and figure 4.1.4.

4.2.3 Analysis

Descriptive statistical analysis and normality testing via Shapiro-Wilks test were performed using GraphPad Prism version 9.2.0 for macOS; GraphPad software, San Diego, California, www.graphpad.com. A normal distribution was demonstrated in both TIR and HbA1c prior to, but not post Loop use, with additional skewed

distributions seen in age and QOL outcome measures. Data are therefore reported as median (IQR) and non-parametric tests utilized in analysis of this cohort, with statistical significance defined as a p value <0.05. Paired groups were compared using Wilcoxon signed rank and unpaired data with the Mann-Whitney test, in addition to correlation of variables using Spearman correlation coefficient.

Qualitative interview outcomes were coded deductively using NVivo 12 QSR; Melbourne, Australia, www.qsrinternational.com [19], following data-driven inductive generation of code structure (available in appendices figure 4.1.2) amongst the research team, with consideration of themes generated in previous DIY AID user interview studies during this process [20,21,22]. Overarching themes were constructed from the participants viewpoints and reflexive thematic analysis performed by a single researcher (AM) [23].

4.3 Results

Twenty-four adults with type 1 diabetes took part in this cross-sectional study, median (IQR) age 33 (27.5-44.8) years and duration of diabetes 21.5 (17.3-32.0) years. All 24 participants were using Loop as their method of insulin delivery, for a duration of 18 (12-25) months, with a total of 470 months or 39.2 years Loop use in the cohort. Demographics of this cohort of Loop users are described in table 4.1. The majority were female (67%), White (92%) and over one third (37.5%) were employed as healthcare professionals; three nurses, a paramedic, a doctor, a physiotherapist, an occupational therapist, a speech and language therapist and a pharmacist.

Table 4.1 Characteristics of Study Participants [*]

Characteristic	Study group, n= 24
Age (years)	33 (27.5-44.8)
Duration of Diabetes (years)	21.5 (17.3-32.0)
Duration of Loop (months)	18.0 (12.0-25.0)
Sex	
Male	8 (33.3)
Female	16 (66.7)
Ethnicity	
White	22 (91.7)
South Asian	1 (4.2)
Mixed race	1 (4.2)
Educational Attainment	
Master's degree	4 (16.7)
University degree	12 (50)
Post-secondary certification/diploma	5 (20.8)
High school	3 (12.5)
Occupation	
Healthcare Professional	9 (37.5)
Public servant	5 (20.8)
Student	3 (12.5)
Teacher	2 (8.3)
Engineer	2 (8.3)
Electrician	1 (4.2)
Project manager	1 (4.2)
Retired	1 (4.2)
Method of insulin delivery prior to Loop	
CSII	23 (95.8)
MDI	1 (4.2)
Glucose sensor use prior to Loop	
Real time CGM	20 (83.3)
Intermittently scanned CGM	3 (12.5)
No sensor	1 (4.2)

[*] Data are median (IQR) or n (%)

4.3.1 Glycemic outcomes

HbA1c values were available both pre and post Loop for all participants. CGM data were available for 6 months prior to Loop for 17 of the 24 study participants. No significant differences in age, duration of diabetes, duration of Loop use, baseline HbA1c or QOL outcome measure scores were seen between those participants with and without pre-Loop CGM data. Pre-Loop; HbA1c 7.9% (7.6-8.3) and TIR 58.0% (52.3-64.0). A statistically significant improvement in these parameters was seen with Loop (p=0.001 and p=0.005). Increased TIR was seen in 82.4% of Loop users; 15% (6.3-23.8%). Pre-Loop 18% of users achieved the clinical target of 70% TIR, in comparison to 67% with Loop use. HbA1c reduction was seen in 79% of users with Loop; improvement 0.8% (0.28-1.18). A significant reduction in TAR was additionally demonstrated with the introduction of Loop (p=0.008). Glycemic data is demonstrated in table 4.2, figure 4.1 and 4.2.

Table 4.2. Glycemic outcomes with Loop use *

Glycemic measure	Pre-Loop	Loop	p value
HbA1c (%)	7.9 (7.6-8.3)	7.1 (6.5-7.5)	0.001
% TIR (3.9-10mmol/L)	58.0 (52.3-64.0)	76.5 (64.6-81.9)	0.005
% TBR 3.0-3.9mmol/L	1.5 (1.0-2.8)	1.3 (0.6-2.4)	0.166
% TBR <3.0mmol/L	0.5 (0.5-0.8)	0.5 (0.5-0.5)	0.531
% TAR (>10mmol/L)	40.0 (31.5-46.5)	21.8 (15.4-33.25)	0.008
Target HbA1c (<7%)	2 (8.3%)	10 (42%)	
Target TIR (>70%)	3 (18%)	16 (67%)	

* Data are median (IQR) and n (%). Wilcoxon signed rank test used to compare glycemic outcomes pre-Loop and with Loop use

Figure 4.1 HbA1c Pre-Loop and with Loop use *

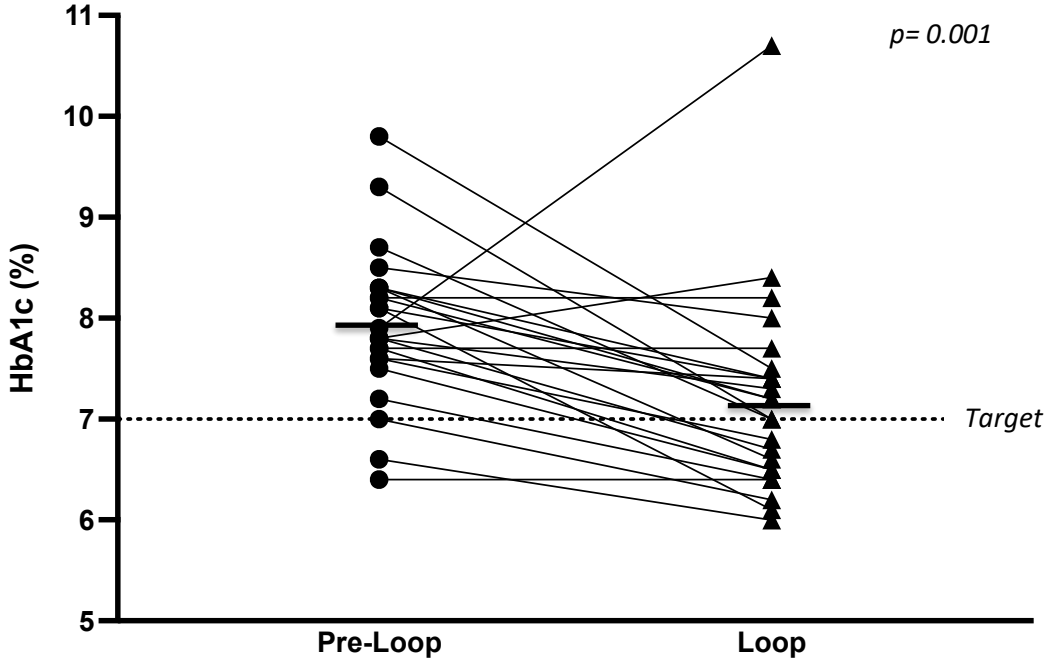
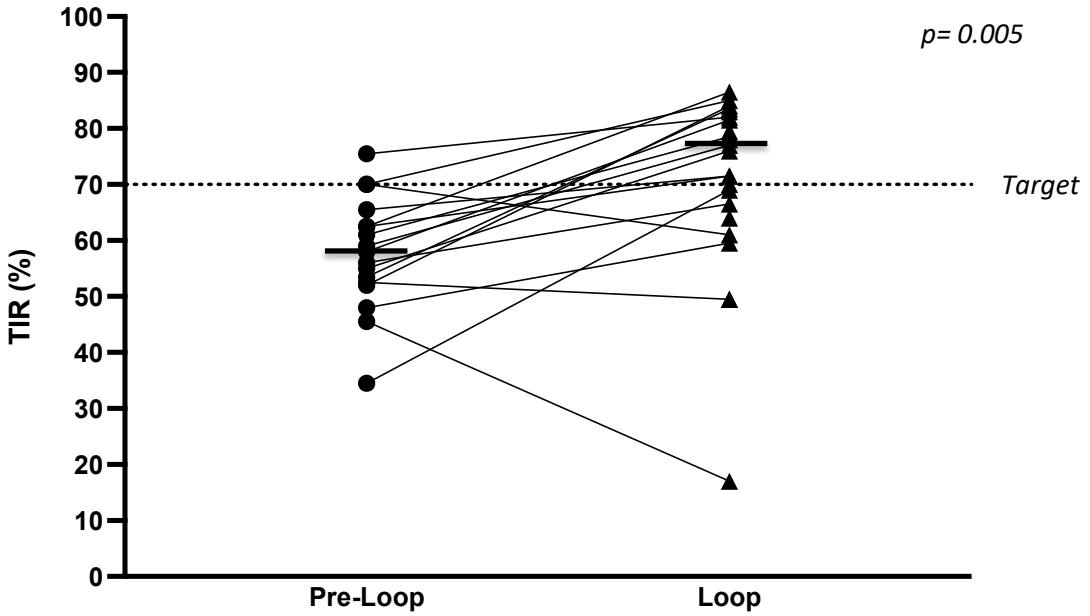


Figure 4.2 TIR Pre-Loop and with Loop use *



* HbA1c readings Pre-Loop and with Loop use, median score line and individual values plotted. Demonstrating the number of individuals achieving a target HbA1c of <7% at each timepoint

* TIR Pre-Loop and with Loop use, median score line and individual values plotted. Demonstrating the number of individuals achieving a clinical target TIR >70% at each timepoint

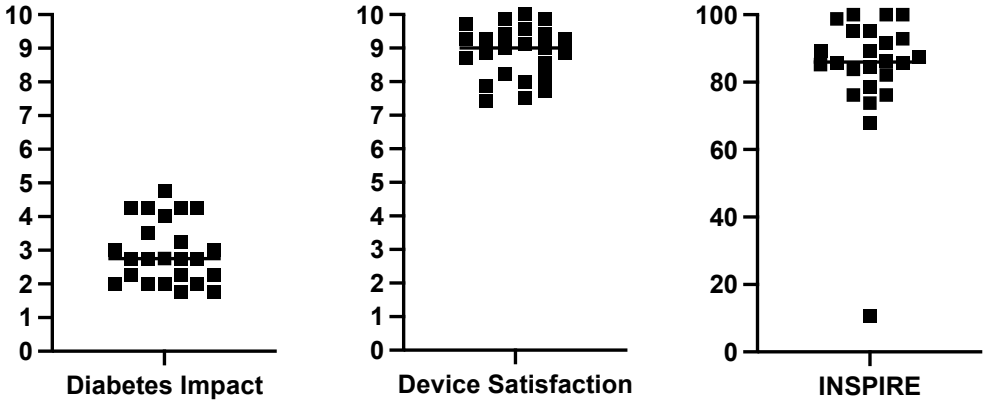
4.3.2 Safety

In the 24 participants, two participants each experienced a single episode of DKA, and no episodes of SH occurred in the cohort with Loop use. One episode of DKA was euglycemic, associated with gastrointestinal infection and SGLT2 inhibitor use, requiring hospital admission for four days including Intensive Care Unit (ICU) stay, with complete resolution. The other was documented to be associated with a urinary tract infection, ICU care was not required and no insulin pump or Loop system failure identified. These episodes of DKA occurred 15 and 11 months following starting Loop.

4.3.3 Quality of Life Measures

QOL measures collected following participant interviews using the DIDS and INSPIRE questionnaires are shown in figure 4.3 and table 4.3. Diabetes Impact (DI) score was 2.8 (2.1-4.8) out of a maximum 10, with a lower score indicating a better outcome. Device Satisfaction (DS) was 9.0 (8.2-9.4) out of 10, with a higher score indicating a better outcome. INSPIRE total score was 86.0 (79.5-94.6) with 100 being the maximum and optimal score. An examination of the relationship between these QOL scores and glycemic variables showed no significant positive correlations with TIR (r=0.024, 0.007 and 0.207, p = ns), nor with HbA1c (r= -0.163, -0.287 and -0.254, p = ns). There was a moderate correlation demonstrated between increased duration of Loop use and lower DI score (r=-0.420, p=0.041).

Figure 4.3 Quality of Life Outcome Measures with Loop use *



* Scatter plots demonstrating Diabetes Impact (DI) out of 10 with a lower score better, Device Satisfaction (DS) out of 10 with a higher score better, and INSPIRE scores out of 100 with a higher score better. Median score line and individual values plotted

Table 4.3 Quality of Life outcomes with AID system use; comparison of Loop use in this cohort with Tandem Control-IQ in two other cohorts [16, 31]

Quality of Life Measure	Outcome with Loop use*	*Tandem Control-IQ* *1.*	*Tandem Control-IQ* *2.*
Diabetes Impact (maximum 10)	2.8 (2.1-4.8)	*2.7 (1.8-3.7)*	
Device Satisfaction (maximum 10)	9.0 (8.2-9.4)	*9.1 (8.4-9.8)*	
INSPIRE score (maximum 100)	86.0 (79.5-94.6)		*87 (77.6-96.5)*

4.3.4 Qualitative interview outcomes

Semi-structured interview data analysis highlighted frequent topics that participants had expressed to be important in their lived experience of Loop use. Overarching themes were constructed from these viewpoints, comprising; empowerment and control, the daily impact of living with diabetes with Loop use, quantification of risk and society's understanding and awareness of Loop (table 4.4).

* Data with Loop are median (IQR)

1. 2 months Tandem Control-IQ use [16], data are mean (IQR)

2. 6 months Tandem control-IQ use [31], data are mean (IQR)

Table 4.4. Thematic analysis outcomes with user experience examples

Theme	**User experience** **[user age, gender, duration of diabetes in years, duration of Loop use in months]**
Empowerment and Control	The control I get; recognizing that I will go low and it stops the insulin. Loop provides more flexibility and personalization, and it's more in my control, that's why I would stick with a DIY over a Commercial system. [31 F, 21yr DM, 12m Loop]
	I feel a lot better all the time. My TIR is so much better. I have more freedom; I feel there is a little bit of that every time you get a device. Having Loop going on in the background to catch any mistakes is great. It makes me sleep better at night. [24 F, 14.5yr DM, 5m Loop]
	I just feel that my control in my worst weeks with Loop are like my glucose levels in the best weeks when I was self-managing. I feel like Loop is like having a holiday from diabetes. [29 F, 27yr DM, 7m Loop]
	Yes, just to note that the system has been so empowering. This disease can make you feel very powerless. [49 F, 37yr DM, 7m Loop]
The daily impact of living with diabetes with Loop use	It has taken the hourly weight of diabetes off. Loop is the best thing that has entered my life. [33 F, 22yr DM, 18m Loop]
	I have better control, reduced time worrying about diabetes but I would say I am spending more time managing my diabetes currently, as the system is relatively new to me. [48 F, 35yr DM, 3m Loop]
	Using Loop there are more things to have to worry about, more tech to charge and make sure you have all the pieces with you when you go places, just more stuff to remember. [31 F, 21yr DM, 12m Loop]
	Ordering the RileyLink took a while. Then there was the time- building it, waiting. The financial aspect and finding the supplies. If you want to be on a Medtronic pump it is difficult to find one (522 or 722), or they are being sold for a very expensive price. [27 F, 22yr DM, 40m Loop]
Quantification of risk	Yes, but I think there are risks to everything. There are risks to crossing the street, but that doesn't mean you would never cross the street does it. As long as you take the time to figure out and correct your ratios

	and put all the correct information into the system, you definitely get out what you put in. You just really need to know your diabetes. [24 F, 17yr DM, 39m Loop]
	Yes, it is safer than a regular pump- they remove the emotional element and decision-making and prevent snap decisions being made. The system is safe once the settings are correct, it is not safe with incorrect settings. [51 M, 32yr DM, 17m Loop]
	There is a risk of the software being incorrect as the builders don't have the resources to test like big tech companies but at the same time anyone can review the algorithm so it is subject to a lot of scrutiny. I do worry what will happen if the developers move on to other projects. [72 M, 19yr DM, 18m Loop]
	Yes, it is safe. The only thing that I sometimes think about is the issue that the Dexcom can have and how Loop only acts according to the information it gets from Dexcom. I have no actual issues with Looping itself. [24 F, 14.5yr DM, 5m Loop]
Society's understanding and awareness of Loop	I feel like it is just me and no one knows about it. Sometimes it can be a little bit lonely. [22 F, 12yr DM, 12m Loop]
	The Looped Facebook group was the biggest thing. Loop docs website was very easy to follow. Support from diabetes team, I felt pretty lucky because there are other physicians that don't approve of loop or help you with it, I know. [27 F, 22yr DM, 40m Loop]
	I have had zero support since starting. I haven't reached out to my DN and she may have been able to help, but pregnancy endos had no idea and were encouraging me to stop Looping even though I had found Loop very beneficial during pregnancy, especially in maintaining tight targets and avoiding severe hypoglycemia. [29 F, 22yr DM, 25m Loop]
	My family were not supportive at first, they were not sure until they saw the a1c and how it worked. My care team's lack of support also scared them, but now my family is very supportive. Also, my partner is very supportive, he would stay up to make sure it was working properly. [24 F, 12yr DM, 15m Loop]

4.3.4.1 Empowerment and Control

The principle of autonomy, with individual choice in selecting an optimal management regimen for their condition, best suited to and most beneficial to them, was a prominent feature in why participants had chosen Loop. The feeling of dissatisfaction with a prior treatment was described, with the need to make an individual choice to optimize their lifestyle.

> *'Honestly in my work I felt like I needed the added security, something better than my pump. I had heard about Loop through social media and a diabetic influencer, I didn't even know if I could do it in Canada, but enquired through the internet and then worked through the shared information on set up.' [24 F, 17yr DM, 39m Loop]*

Control was a term that participants frequently mentioned, referring both to this treatment choice component as well as glucose targets. The majority included improvements in TIR and HbA1c as both motivating factors to commence, and prominent benefits of Loop use. Increased lifestyle flexibility; particularly relating to both diet and exercise patterns were commonly reported benefits.

> *'I have more time and don't have to worry as much about what I eat. I feel more flexible in eating schedules and working out. With Loop I can eat whenever I want and exercise when I want to, I can eat a surprise high carb meal for example.'* [24 F, 12yr DM, 15m Loop]

Another important benefit was the ability to sleep well overnight, being able to rely on Loop to ensure safety, particularly to avoid nocturnal hypoglycemia. Multiple participants reported struggling with nocturnal hypoglycemia prior to implementing Loop.

> '*A year prior to looping I was having a lot of night-time lows and not waking up (didn't feel them, didn't hear CGM alerts), and would get phone calls from my mom.'* [27 F, 22yr DM, 40m Loop].

It was apparent that Loop offered peace of mind to both the user and their friends and family by preventing nocturnal hypoglycemia. Individuals who had struggled with

this previously described the importance of this new aspect of control that Loop had enabled.

> *'Having Loop going on in the background to catch any mistakes is great. It makes me sleep better at night.'* [24 F, 14.5yr DM, 5m Loop].

4.3.4.2 The daily impact of living with diabetes with Loop use

Participants discussed the psychological impact of living with diabetes both prior to and since using Loop, with notable improvements expressed in time spent thinking about diabetes and diabetes-related distress.

> *'Especially for people diagnosed relatively late, whose whole lives have changed, especially with the mental health aspect that diabetes has put a veil over your life, Loop has really helped to stop diabetes being a nuisance and instead it is managed.'* [24 F, 17yr DM, 39m Loop]

Burnout as a result of day-to-day demands was reported, and despite the beneficial impact of Loop on psychological wellbeing expressed by participants, it was noted that starting to use the system and the initial set up, required a significant investment of time and energy.

> *'I felt burnout in managing my diabetes, spending all my time managing diabetes or filling out insurance forms for my diabetes, it was a real mental challenge to think about and set up a new system, a lot of mental energy.'* [29 F, 27yr DM, 7m Loop].

Significant financial investments, both initial and ongoing, were reported by Loop users. They required both the component technology (an insulin pump and CGM) and appropriate devices on which to set up and utilize the app; an iPhone with iOS 12.4 or newer and Mac computer, as well as a communicating device (RileyLink, OrangeLink or EmaLink) and an Apple developers' license [24]. Access to, and cost of this hardware was the most commonly perceived barrier to Loop use in this cohort.

> *'I would recommend everyone to try it. It is quite a bit of work getting it setup and getting it ready but is pretty minimal effort for upkeep. The access to the devices is the one thing that makes it difficult (especially coverage for it). The peace of mind*

makes it worth it because it makes so much of a difference.' [24 F, 14.5yr DM, 5m Loop]

Use of a system such as Loop comprising multiple devices, consequently requires users to ensure all necessary components are carried with them and have sufficient battery charge. The devices must be in constant communication with one another to effectively utilize the app. Some participants reported these day-to-day aspects of Loop use to be challenging at times.

'Using Loop there are more things to have to worry about, more tech to charge and make sure you have all the pieces with you when you go places, just more stuff to remember.' [31 F, 21yr DM, 12m Loop]

4.3.4.3 Quantification of risk

Because Loop is unregulated and therefore unsupported there may be perceptions of risk. When asked regarding this, none of the participants considered that using Loop was any more of a risk than alternate options in diabetes management. Indeed, the majority deemed it to be of much lower risk.

'*Yes definitely, I am more concerned for the people who don't use Loop than those who do. It is safer to have a computer system shutting off your insulin and stopping you from going low. It is more trustworthy and makes more rational decisions compared to a person; it shuts off those irrational and emotive decisions so yes, I think it is safer.'* [30 M, 15yr DM, 44m Loop]

The importance of setting up the system correctly, 'knowing your diabetes' in terms of having the correct insulin pump settings prior to commencing Loop was expressed by the majority of participants.

'I think the only real risk is if there is a lack of understanding that is when problems will arise. I think the system would be risky for newly diagnosed people because we don't leave the doctor's office after that first appointment knowing everything, we need to know how to make these systems work. It is a stepwise process but if the settings are set up correctly then I don't think there are any risks.' [49 F, 37yr DM, 7m Loop]

Limitations of individual components (insulin pump or CGM device), rather than the Loop system itself were identified as a source of issues which arose.

> *'Another challenge or a risk I find during the times when there is a sensor change and the Dexcom is in its warm up period, if the blood sugars haven't been linking for 2 hours and then it starts, Loop tends to over correct and risks dropping my blood sugars low (which has happened more often than not) it can be a bit better if I allow it to autocorrect.'* [33 F, 22yr DM, 18m Loop].

Many participants are using older and out-of-warranty pumps (because many newer in-warranty pumps are incompatible with the Loop app) which they identified as a potential risk in itself.

> *'I was worried about using the older pump but I have recently acquired both a backup pump and RileyLink so have more confidence in this. My pump looks really rough and I do worry occasionally about button errors especially in the heat*.' [29 F, 27yr DM, 7m Loop]

Participants reported dissatisfaction with alternate diabetes management options available, including Commercial AID systems. One participant had used the Medtronic 670G but struggled with the Enlite sensor, especially with alarms. Another user was dissatisfied with Tandem Control-IQ as a result of the lack of customizable glucose targets, with the system providing fixed thresholds which some people feel are too high. Many expressed they would not wish to consider any other options now that they have experienced Loop.

> *'I feel that Loop is the best option there is right now for people with type 1 diabetes, pump companies are not there yet. I like that people with type one diabetes have built these systems and the #wearenotwaiting movement; the principles and practice of these very gifted individuals who have helped so many people with this technology. I am very thankful to them and just wish more people could have access to it.'* [33 F, 18yr DM, 23m Loop].

4.3.4.4 Society's understanding and awareness of Loop

Due to the unregulated nature of Loop, some participants expressed concern in discussing use of Loop with others including healthcare providers. All participants in this study were seen in the same diabetes clinic, although with multiple different care providers practicing within the clinic. The majority expressed very positive interactions in the healthcare setting, frequently describing "passive encouragement" to consider and utilize Loop. One participant explained that due to lack of support, with discouragement of Loop by her previous healthcare team, she had moved to a new provider as she wished to continue using Loop. Another described being discouraged to continue Loop, whilst seeing a different endocrinologist during pregnancy, despite finding it very beneficial. All other participants felt they could discuss Loop with their clinical team without concern and that healthcare providers were largely keen to learn more about Loop.

> '*Yes, my healthcare team is very supportive. I have had no negative interactions; I was admitted to the medicine unit – they saw my chart and brought the team in and wanted me to talk about looping and everyone thought it was really cool.'* [27 F, 22yr DM, 40m Loop]

The majority of participants felt that their family and friends were supportive of Loop, although several noted that some had reservations at first, before seeing the benefits of the system for themselves.

> *'There was some hesitancy from my family at first because it's not government approved; you're tinkering with it yourself. I see DIY looping as the same as playing around with a pump for programming. Everyone is supportive now. I have friends with diabetes that I have started on loop.'* [24 M, 4.5yr DM, 25m Loop].

Many of the participants had recommended or assisted another person with diabetes in starting Loop, but indicated that the system would not be beneficial for everyone, and felt that prior diabetes education and an understanding of technology were crucial.

> *'Yes, I have helped lots of people with looping, but I would tailor that recommendation based on the individual. Only if they have a good understanding*

of diabetes management and can critically think through how the system is reacting and what is going on, and interpret the data.' [33 F, 22yr DM, 18m Loop]

Social media, most frequently the Looped Facebook group [25], was a key support structure that all participants had used either currently or previously to set up and/or trouble-shoot Loop. Some noted that through this they had been partnered with a current Loop user in a mentor role, to provide further support with starting Loop.

'Yes, Looped Facebook group is amazing and so responsive. I also use Alberta diabetes group, Loop and learn and an OrangeLink group. I was set up with a mentor in the Looped group when starting Loop also.' [48 F, 35yr DM, 3m Loop]

Users expressed frustration at the lack of industry support for Loop and the fact that it had required people with diabetes themselves and their families to build this system. However, concern was also expressed relating to future industry involvement with Loop and the potential changes in the system this may involve.

'*I do worry with the increasing success the system may be 'dumbed down' in the future and restricted flexibility especially if it is undergoing regulatory approvals with bureaucracy and authorities changing the system.*' [44 F, 32yr DM, 20m Loop]

4.4 Discussion

In this cohort of adults with type 1 diabetes at a single centre, we have highlighted improved glycemic outcomes with Loop use. With this glucose management system 67% of these users achieved the recognized clinical target of 70% TIR [26]. In this first described Canadian cohort of Loop users we have identified high QOL scores with Loop. These Loop users demonstrate superior glycemic outcomes, relative to the general population of people with type 1 diabetes, with 42% achieving an HbA1c <7%, in comparison to the reported average 21% [12]. Users noted the removal of an emotive decision-making component of diabetes management to be an overwhelmingly favorable aspect of Loop, felt to aid in the achievement of individualized glucose targets. The safety features of Loop were particularly felt to be important by our participants overnight, with associated improved sleep. A reduction

in hypoglycemia (frequency and severity), improved overnight glycemic control and improved sleep have been widely reported with all DIY AID system types [2, 7, 27].

We have demonstrated a strikingly similar TIR reported to that in a large prospective observational study of 558 US residents, mean (SD) 23 years (13) with new Loop use for six months [9]. In this large cohort, with a maximum of seven days Loop experience at baseline, at six months mean (SD) TIR was 73% (13), with 71% (16) in the most recent six months of Loop use in our local cohort of 24 users. In contrast to this prospective study, our study participants are relatively experienced Loop users, with a median (IQR) 18 months (12-25) of Loop use. These results suggest that the benefits of Loop can occur early in its implementation and are somewhat durable, a desirable characteristic for a therapeutic intervention in a chronic condition like type 1 diabetes.

No adverse safety outcomes related to hypoglycemia with Loop use were reported in our data; an improvement in TBR, time <3.0mmol/L and no admissions with SH. However, two episodes of DKA occurred, both of which were associated with underlying infections. In people with type 1 diabetes, the estimated incidence of DKA is reported to be 4.6-8.0 events per 1000 patient years [28]. Lum et al reported no episodes of DKA with six months of Loop in 558 individuals (279 patient years) and 51 episodes of SH, with just one of these attributed to Loop [9]. This larger prospective study utilized weekly electronic messages for data collection (with an 89% response rate), in order to maximize user recall, but was dependent on self-reporting of these likely memorable and significant events for a person with diabetes [29]. Our data was reported based on retrospective recall from participants at the time of interview but was verified by review of medical records. Just one of the two participants in our cohort had self-reported the occurrence of an episode of DKA. All participants in our study reported that they perceived Loop to be safe, when the correct settings are in place. DIY AID systems were primarily designed for safety, initially targeting the avoidance of hypoglycemia. This concept of risk reduction through AID system use, has been discussed by Dana Lewis; highlighting the importance of taking level of risk with AID use into context, with the risk faced by a person with diabetes who is manually dosing insulin representing the most appropriate comparator- not the risk

of people without diabetes. Use of AID systems removes a proportion of this total risk and provides an overall net risk reduction for people with type 1 diabetes [30].

In terms of quantitative QOL outcomes, we found a low Diabetes Impact and both high Device Satisfaction and INSPIRE scores with Loop use for a median of 18 months in our cohort. The scores were very similar to DIDS outcomes, with two months of Tandem Control-IQ use (Commercial AID) in 1435 people with type 1 diabetes 14 years and older [14]; with Diabetes Impact 2.7 (2.8 in this cohort) and Device Satisfaction 9.1 (9.0). INSPIRE outcomes were also comparable to those reported with 6 months of Tandem Control-IQ use in another cohort of 112 users; mean 87 (86 in this cohort) [25]. TIR achieved with Tandem Control-IQ was similar to our cohort; 79.2% (70.3-86.2), with a shorter duration of AID use, but closer to target glycemia at baseline; HbA1c 6.9% (SD 0.9) [14]. These studies of Commercial AID [16, 31] were conducted with substantially more supervision and support, as would be expected in an RCT, in comparison to the real-world experience collected from our Loop users.

We did not see a strong correlation between QOL outcome measures and glycemic outcomes in this cohort. This may be a result of small sample size, with a narrow spectrum in these outcomes, but our qualitative data highlights a strong benefit of Loop use on QOL. Following improved glycemic outcomes, enhanced QOL was the most frequently reported benefit with Loop use in this cohort. This concept comprised a reduction in the psychological impact of living with diabetes; time spent thinking about diabetes, diabetes-related distress and burnout, in addition to greater flexibility in day-to-day life, notably relating to diet and activity. The reduced mental burden of diabetes and less reliance on the accuracy of carbohydrate counting are consistently reported positive outcomes with DIY AID system use [2].

Another common theme identified was the financial resources required for Loop use restricting the availability of this beneficial system. We did not collect data relating to income or index of deprivation, but our participants educational attainment and occupations indicate higher than average socio-economic status [32]. Access and coverage of insulin pumps across Canada remains unequal, with varying provincial

healthcare funding models in place; insulin pump therapy is more commonly utilized in areas with reimbursement programs in place [33].

All except one Loop user in this cohort used both an insulin pump and CGM device at the time of deciding to commence Loop. Having the access to, but frequently the dissatisfaction with these devices, were contributing factors to the process of behavior change in these users. In order for effective behavior change to occur, such as the initiation and continuation of Loop there are key components for the user and their environment according to the COM-B model of behavior change. These include capability (both physical and psychological), physical (including financial and material) and social opportunity (considering social and cultural norms), as well as the motivation for change [34]. Components of this model are apparent in the lived experience we have described. Loop users highlighted the importance of this physical opportunity, with availability and access to technological devices, as a potential limiting factor in the initiation of Loop. The majority of participants found their healthcare providers to be relatively supportive of commencing Loop, despite the system being un-regulated. This 'social opportunity' enabled reassurance for users, of this being an acceptable behavior change. This positive interaction is by no means guaranteed, with variable experiences reported with DIY AID use in the healthcare setting [35].

This study has some strengths and weaknesses, the cohort were recruited from a single centre with an integrated medical record that would capture admissions to any facility in the province. Objective collection of this data was performed by the healthcare team, rather than self-reported by users themselves, which has been a weakness in the majority of previous reports of DIY AID systems which describe glycemic outcomes [2,7,10, 11, 27, 36-38]. The study did not incorporate a comparator control group. We have collected qualitative in addition to quantitative data, with Loop users able to compare their own lived experiences both with and without Loop use. The sample size was small for collection of quantitative outcome data, limited by the number of Loop users locally. Selection bias, as a result of inclusion of individuals who have chosen to use Loop, must be considered in the generalizability of our findings to the wider population of people with type 1 diabetes. We have only

included current Loop users and therefore have not been able to explore the reasonings behind why users may decide to stop using this form of glucose management system. Fear of disapproval of Loop use from a diabetes provider as well as barriers to acquiring the component devices have been reported as reasons for Loop discontinuation [22], although we cannot estimate whether this is a significant factor in our cohort of individuals who had shared their DIY AID use with their healthcare providers.

4.5 Conclusion

DIY AID use in this local cohort of individuals who have chosen to start, and continue to use Loop, has been associated with notable improvements in glycemic outcomes and excellent QOL. Through a combination of quantitative data collection and qualitative interview analysis, we have gained a greater understanding of the lived experience of Loop use in this cohort, including common challenges as well as extensive benefits. Most striking is the ability for motivated individuals to further increase their success in achieving glycemic targets whilst simultaneously experiencing a reduced burden and distress from diabetes. While, to date most DIY users have been those who were already successful, future studies should focus on the potential benefits of DIY AID for people who have found it difficult to achieve glycemic targets because it has been excessively burdensome or beyond their capacity because of limited financial, social or educational resources. It is hoped that the experience of Loop users described in this cohort, in combination with this broader user experience, may be used to guide how and for whom, this system may benefit many other future users.

4.6 References

1. Leelarathna L, Choudhary P et al. Hybrid closed-loop therapy: where are we in 2021? Diabetes, Obesity and Metabolism. 2020; 23(3): 655-660.

2. Jennings P and Hussain S. Do-It-Yourself Artificial Pancreas Systems: A Review of the Emerging Evidence and Insights for Healthcare Professionals. Journal of Diabetes Science and Technology. 2019; 14(5): 868-877.

3. Roberts JTF, Moore V and Quigley M. Prescribing Unapproved Medical Devices? The Case of DIY Artificial Pancreas Systems. Medical Law International. 2021.

4. Wu Z, Luo S et al. Use of a do-it-yourself artificial pancreas system is associated with better glucose management and higher quality of life among adults with type 1 diabetes. Therapeutic advances in endocrinology and metabolism. 2020; 25:11: 204.

5. Petruzelkova L, Jiranova P et al. Pre-school and school-aged children benefit from the switch from a sensor-augmented pump to an AndroidAPS hybrid closed loop: A retrospective analysis. Paediatric Diabetes. 2021; 22(4): 594-604.

6. Gawrecki A, Zozulinska-Zoilkiewicz D et al. Safety and glycemic outcomes of do-it-yourself AndroidAPS hybrid closed-loop system in adults with type 1 diabetes. PLoS One. 2021; 5: 16(4).

7. Lewis D and Leibrand S. Real-World Use of Open Source Artificial Pancreas Systems. Journal of diabetes science and technology. 2016; 10(6): 1411.

8. Melmer A, Zuger T et al. Glycaemic control in individuals with type 1 diabetes using an open source artificial pancreas system (OpenAPS). Diabetes, obesity & metabolism. 2019; 21(10): 2333- 2337.

9. Lum J, Bailey R et al. A Real-World Prospective Study of the Safety and Effectiveness of the Loop Open-Source Automated Insulin Delivery System. Diabetes technology & therapeutics. 2021; 23(5): 367-375.

10. Street TJ. Review of Self-Reported Data from UK Do-It-Yourself Artificial Pancreas System (DIYAPS) Users to Determine Whether Demographic of Population Affects Use or Outcomes. Diabetes Therapy. 2021.

11. Braune K, Gajewska K et al. Why #WeAreNotWaiting—Motivations and Self-Reported Outcomes Among Users of Open-source Automated Insulin Delivery Systems: Multinational Survey. Journal of Medical Internet Research. 2021; 23(6).

12. Foster M, Beck R et al. state of Type 1 Diabetes Management and Outcomes from the T1D Exchange in 2016-2018. Diabetes Technology and Therapeutics. 2019; 21(2): 66-72.

13. Litchman M, Lewis D, Kelly L and Gee P. Twitter Analysis of #OpenAPS DIY Artificial Pancreas Technology Use Suggests Improved A1C and Quality of Life. Journal of diabetes science and technology. 2019; 13(2): 164-70.

14. Zoom Video Communications Inc. (2016). Security guide. Zoom Video Communications Inc. available at; https://d24cgw3uvb9a9h.cloudfront.net/static/81625/doc/Zoom-Security-White-Paper.pdf, last accessed 15th October 2021.

15. Manning M, Singh H, Stoner K and Habif F. The Development and Psychometric Validation of the Diabetes Impact and Device Satisfaction Scale for Individuals with Type 1 Diabetes. Journal of Diabetes Science and Technology. 2020. 14(2): 309-317.

16. Pinkser J, Muller L. Real-World Patient-Reported Outcomes and Glycemic Results with Initiation of Control-IQ Technology. Diabetes Technology & Therapeutics. 2021. 23(2): 120-127.

17. Weissburg-Benchell J, Shapiro JB at al. Assessing patient-reported outcomes for automated insulin delivery systems: the psychometric properties of the INSPIRE measures. Diabetic Medicine. 2019. 36(5): 644-652.

18. INSPIRE questionnaire for adults, available at https://static1.squarespace.com/static/5a138c2df6576e7fb23868e8/t/5f12309765d7c723e00c13be/1595027607811/INSPIRE+Questionnaire+for+Adults+post+assessment+FINAL+VERSION+17th+June+2020.pdf, last accessed 15th October 2021.

19. QSR International Pty Ltd. (2020) NVivo (released in March 2020), available at; https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home.

20. Schipp J, Skinner T et al. How adults with Type 1 Diabetes Are Navigating the Challenges of Open-Source Artificial Pancreas Systems: A Qualitative Study. Diabetes Technology and Therapeutics. 2021.23(8):546-555.

21. Schipp J, Skinner T et al. 'We're all on the same team'. Perspectives on the future of artificial pancreas systems by adults in Australia with type 1 diabetes using open-source technologies: A qualitative study. Diabetic Medicine. 2021. 29th September: 1-7.

22. Wong J, Suttiratana S and Lal R. Discontinued Use of the Loop Insulin Dosing System: A Mixed-Methods Investigation. Diabetes Technology and Therapeutics. 2021. 10.1089/dia.2021.0362.

23. Braun V and Clarke V. Using thematic analysis in Psychology. Qualitative Research in Psychology. 2006. 3: 77-101.

24. LoopDocs, available at https://loopkit.github.io/loopdocs/, last accessed 5th February 2022.

25. Looped Facebook Group available at www.facebook.com/groups/TheLoppedGroup, last accessed 7th February 2022.

26. Battelino T, Danne T et al. Clinical Targets for Continuous Glucose Monitoring Data Interpretation: Recommendations from the International Consensus on Time in Range. Diabetes Care. 2019; 42(8):1593-1603.

27. Hng TM and Burren D. Appearance of Do-It-Yourself closed-loop systems to manage type 1 diabetes. Internal Medicine Journal. 2018; 14 (11): 1400-1404.

28. Kitabchi AE, Umpierrez GE, Murphy MB, et al. Hyperglycemic crises in adult patients with diabetes: A consensus statement from the American Diabetes Association. Diabetes Care 2006; 29:2739–48.

29. Booth GL, Fang J. Acute complications of diabetes. In: Hux JE, Booth GL, Slaughter PM, et al., eds. Diabetes in Ontario: An iCES practice atlas. Toronto: Institute for Clinical Evaluative Science (ICES), 2003.

30. Lewis D. Errors of commission or omission: The net risk safety analysis conversation we should have around automated insulin delivery systems. Diabetic Medicine. 2021; e14687.

31. Kudva Y, Laffel L et al. Patient-Reported Outcomes in a Randomized Trial of Closed-Loop Control: The Pivotal International Diabetes Closed-Loop Trial. Diabetes Technology and Therapeutics. 2021; 23(10): 673-683.

32. Lyche, CS. Taking on the completion challenge: A Literature review on policies to prevent dropout and early school leaving. Organization for Economic Co-operation and Development. 2010.

33. Song C, Booth G, Perkins B and Weisman A. Impact of government-funded insulin pump programs on insulin pump use in Canada: A cross-sectional study using the National Diabetes Repository. BMJ Open Diabetes Research and Care. 2021; 9:e002371.

34. West R, Michie S. A brief introduction to the COM-B Model of behaviour and the PRIME theory of motivation. Qeios, CC-BY 4.0. April 9, 2020.

35. Crabtree TSJ, Choudhary P et al. Health-care professional opinions of DIY artificial pancreas systems in the UK. Lancet Diabetes and Endocrinology. 2020; 8(3): 186-187.

36. Braune K, O'Donnell S et al. Real-World Use of Do-It-Yourself Artificial Pancreas Systems in Children and Adolescents with Type 1 Diabetes: Online Survey and Analysis of Self-Reported Clinical Outcomes. JMIR mhealth and uhealth. 2019; 30(7):7.

37. Palmer W, Greely S, Letourneau-Frieburg LR, Naylor R. Using a Do-It-Yourself Artificial Pancreas: Perspectives from Patients and Diabetes Providers. Journal of Diabetes science and technology. 2020; 14(5): 860-867.

38. Herzog AL, Busch J et al. Survey about do-it-yourself closed loop systems in the treatment of diabetes in Germany. PLoS One. 2020; 15(12): 0243.

Chapter 5: General Conclusions and Future Directions

5.1 Conclusions

This thesis has explored the Commercial and DIY Automated Insulin Delivery (AID) systems which are currently available for people with type 1 diabetes in Canada. The extensively reported beneficial outcomes associated with the use of these glucose management systems have been described; notably in glycemia, quality of life and safety, in addition to the challenges posed, particularly surrounding DIY AID. A Scoping Review highlighted the current evidence base surrounding DIY AID systems, to be real-world data; largely self-reported user data and observational studies, with no randomized control trials (RCT).

We have demonstrated through a cross-sectional survey of Healthcare Providers (HCP) across Canada looking after adults or children with type 1 diabetes, a low reported incidence of AID use. The perceived barriers to AID use, and potential future interventions to improve HCP confidence in recommending AID were explored, with the aim of improving access to the benefits of AID. Funding or coverage of technology, in addition to deficiencies in AID-specific education, for both users and HCP, were areas of concern expressed by HCP. The need for clarification in medico-legal guidance, specifically relating to ethical and legal obligations of HCP surrounding DIY AID system use, was another required intervention identified.

Beneficial glycemic outcomes were demonstrated with DIY AID use, through an observational study of a local cohort of Loop users. Participants had chosen to initiate, and continue to use Loop (median 18 months duration), and all attended one clinical centre for their diabetes care. No significant safety concerns were highlighted specific to Loop use and a non-significant reduction in hypoglycemia was seen. Through both outcome measures and semi-structured interviews, users reported an overwhelmingly positive impact of Loop use on their quality of life.

5.2 Limitations

The views and experiences which have been discussed are limited by geographic location; to Canadian HCP, and one clinical centre in the study of Loop users. Expansion of cross-sectional survey responses, to include worldwide data collection, would enable wider HCP experience to be captured and comparisons between areas in both experience, attitudes and practices, to be made. Although differences in organization of care and reimbursement programs would need to be considered in making these comparisons. Observational data collection from DIY AID system users in other clinical centres would enable a greater volume of quantitative outcome data in terms of glycemic, quality of life and safety outcomes. In addition, broader user experiences would be important to identify, particularly relating to user experience in clinical care and interactions with HCP surrounding DIY AID use, which are likely to be more varied across different clinical centres. Conducting an RCT in DIY AID poses challenges, specifically relating to the unregulated nature of the system. Further study of individuals willing to use a DIY system could incorporate a control group in the form of immediate vs delayed start of DIY AID, or direct comparison to Commercial AID within the same individual, using a cross-over study design.

This Loop user cohort study did not include any users who had decided to stop using a DIY system and therefore reasoning as to why this may occur are not known since our participants were solely users who had chosen to, and continue to use a DIY AID system. Identifying users who have found the systems less beneficial, or have chosen an alternate form of insulin delivery or glucose management system, would enable a broader and more inclusive sample of user experience to be explored. Although the data and experiences described by participants in our study were overwhelmingly positive, these negative aspects and experiences are however important considerations in assessing whether potential future users may gain benefit from DIY AID system use. In this, it is important to consider the concept of individual choice and patient preference; some individuals prefer multiple daily injections of insulin and others insulin pumps, as their chosen method of insulin delivery. One specific AID system will not be optimal for all people with type 1 diabetes but the ability to have this choice is key.

5.3 Future Directions

A rapidly expanding body of evidence is available to support the use of DIY AID, this continues to be largely real-world data, potentially subject to bias as a result of sampling and self-reporting by users. In the use of a user-driven, unapproved AID system, with no industry funding, this may however be seen as the optimal and most appropriate means of acquiring outcome data. Although currently, a randomized control trial is ongoing in New Zealand in the use of AndroidAPS, the outcomes of this, and any future similar studies of Loop and OpenAPS are likely to strengthen the existing real-world data and may be important to legitimize this approach for HCP, who rely upon RCT data as evidence of safety and efficacy.

With regards to the Loop system, regulatory approval processes are currently ongoing for Tidepool Loop, with the aim to achieve a regulatory approved app, available on iOS operating systems. If Tidepool Loop receives FDA approval, this is will have potential implications for the system, Loop users, HCP and the wider DIY AID community.

Currently education for HCP in the use of specific Commercial AID system types is available through the manufacturing device company. Without industry support this is lacking for DIY AID systems; the set-up, running and optimization of OpenAPS, AndroidAPS and Loop systems are areas in which the majority of HCP looking after people with type 1 diabetes have little understanding. Specific education in these areas is imperative to enable appropriate and optimal HCP support for people with type 1 diabetes choosing to use this form of glucose management system. Mentors within the DIY AID community, largely apparent through social media platforms, are rich knowledge sources in this field. Future collaboration with these individuals is in no doubt essential, to enable development of targeted education, in this exciting and rapidly expanding field. The development of a position statement from Diabetes Canada guiding the appropriate use of DIY AID would provide further support to HCP in this uncertain area. Co-development of recommendations with both users and experts would be key, with focus upon the multi-dimensional outcomes with this

therapeutic intervention including the patient experience as opposed to a sole focus on the glycemic benefits. Currently, sufficient high-quality evidence in this field may not be available to produce guidance beyond expert consensus.

The AID systems described, are the most technologically advanced management option currently available for people with type 1 diabetes. They are however, an option available to some, to manage a lifelong condition, and by no means a cure. There is great hope from both users and HCP, that these systems are indeed an optimal holding measure and not the final destination in therapeutic interventions for people with type 1 diabetes. Alongside ongoing technological advancements, other avenues must continue to be explored, including cell-based therapies, as well as therapies designed to prevent or reverse type 1 diabetes – with the ultimate hope to reduce the burden of living with diabetes and preventing the negative impact of complications reducing quantity and quality of life.

Bibliography

Ahmed S, Ewens D et al. Do-It-Yourself (DIY) Artificial Pancreas Systems for Type 1 Diabetes: Perspectives of Two Adult Users, Parent of a User and Healthcare Professionals. Advances in Therapy. 2020; 37(9): 3929-3941.

Ahmed S and Gallo S. Looping with Do-It-Yourself Artificial Pancreas Systems During Ramadan Fasting in Type 1 Diabetes Mellitus: Perspectives of a User and a Physician. Diabetes therapy. 2020; 9:1-11.

Alidibbiat A, Alqashami A and Hussain S. An observational study detailing clinical experience, Safety and Efficacy of Commercial and Open-source Automated Insulin Delivery systems in fasting during Ramadan with type 1 diabetes.ATTD. 2021;P056/397.

American Diabetes Association. 7. Diabetes Technology: Standards of Medical Care in Diabetes 2021, available at https://care.diabetesjournals.org/content/44/Supplement_1/S85, last accessed 27th January 2022.

AndroidAPS Documentation, available at https://androidaps.readthedocs.io/en/latest/index.html, last accessed 27th January 2022. https://androidaps.readthedocs.io/en/latest/index.html

Battelino T, Danne T et al. Clinical Targets for Continuous Glucose Monitoring Data Interpretation: Recommendations from the International Consensus on Time in Range. Diabetes Care. 2019; 42(8):1593-1603.

Beato-Vibora P, Gallego-Gamero F and Ambrojo-Lopez A. Real-world outcomes with different technology modalities in type 1 diabetes. Nutrition, Metabolism and Cardiovascular Disease. 2021; in press.

Beck R, Riddlesworth T et al. Effect of Continuous Glucose Monitoring on Glycemic Control in Adults with Type 1 Diabetes using Insulin Injections. JAMA. 2017; 317(4): 371-378.

Bell KJ, Barclay AW et al. Efficacy of carbohydrate counting in type 1 diabetes: a systematic review and meta-analyses. Lancet Diabetes and Endocrinology. 2014; 2(2): 133-140.

Beverly EA, Ganda OP, Ritholz MD. Look who's (not) talking: Diabetic patients' willingness to discuss self-care with physicians. Diabetes Care. 2021; 35(7): 1466-1472.

Beverly EA Worley M et al. Patient-Physician Communication and Diabetes Self-Care. Journal of Clinical Outcomes and Management. 2016; 23: 11.

Booth GL, Fang J. Acute complications of diabetes. In: Hux JE, Booth GL, Slaughter PM, et al., eds. Diabetes in Ontario: An iCES practice atlas. Toronto: Institute for Clinical Evaluative Science (ICES), 2003.

Braun V and Clarke V. Using thematic analysis in Psychology. Qualitative Research in Psychology. 2006. 3: 77-101.

Braune K, Gajewska K et al. Why #WeAreNotWaiting—Motivations and Self-Reported Outcomes Among Users of Open-source Automated Insulin Delivery Systems: Multinational Survey. Journal of Medical Internet Research. 2021; 23(6).

Braune K, Lal R et al. Open-source automated insulin delivery: international consensus statement and practical guidance for health-care professionals. Lancet Diabetes and Endocrinology. Nov 2021;21:00267-9.

Braune K, May M and Thurm U. Safe and Successful Completion of a Half Marathon by an Adult with Type 1 Diabetes Using a Personalized Open-Source Artificial Pancreas System. Journal of Diabetes Science and Technology. 2020; 14(6): 1137-1138.

Braune K, O'Donnell S et al. Real-World Use of Do-It-Yourself Artificial Pancreas Systems in Children and Adolescents with Type 1 Diabetes: Online Survey and Analysis of Self-Reported Clinical Outcomes. JMIR mhealth and uhealth. 2019; 30(7):7.

Braune K, O'Donnell S et al. DIWHY: Factors Influencing Motivation, Barriers, and Duration of DIY Artificial Pancreas System Use among Real-World Users. Diabetes 2019 Jun; 68(Supplement 1).

Buchan v. Ortho Pharmaceutical (Canada) Ltd., 1986 CanLII 114 (ON CA), <https://canlii.ca/t/1npp9>, retrieved on 2022-01-30.

Bukhari K and Malek R. Open-source automated insulin delivery systems for the management of type 1 diabetes during pregnancy. BMJ Case Report. 2021. 14:e243522.

Burnside M, Lewis D et al. CREATE (Community deRivEd AutomaTEd insulin delivery) trial. Randomised parallel arm open label clinical trial comparing automated insulin delivery using a mobile controller (AnyDANA-loop) with an open-source algorithm with sensor augmented pump therapy in type 1 diabetes. Journal of diabetes and metabolic disorders. 2020; 19(2): 1-15.

CADTH. About the Health Technology Assessment Service. June 2021. Available at https://www.cadth.ca/about-health-technology-assessment-service, last accessed 29th January 2022.

CADTH Tool: Off-label drug use. July 2017, available at https://www.cadth.ca/sites/default/files/pdf/off_label_use_of_drugs_pro_e.pdf, last accessed 27th January 2022.

Choi S. Open Artificial Pancreas System Improved Glycemic Control and Quality of Life in patients with type 1 diabetes. Journal of Diabetes Science and Technology. 2018 Mar; 12(2).

Choi SB, Hong ES and Noh YH. Open artificial pancreas system reduced hypoglycemia and improved glycemic control in patients with type 1 diabetes. Diabetes. 2018;67(suppl 1).

Choudhary P, Campbell F, Joule N and Kar P. Diabetes UK Position Statement. A type 1 diabetes technology pathway: consensus statement for the use of technology in type 1 diabetes. Diabetic Medicine. 2019; 36(5):531-538.

Cohen L, Barnard-Kelly K et al. Do-it-yourself Automated Insulin Dosing: Qualitative study exploring user experiences. ATTD. 2021;P053/172.

Cohen L, Naranjo D et al. Do it yourself Automated Insulin Dosing: Qualitative study exploring healthcare professional experiences. ATTD. 2021;O024/173.

Crabtree TSJ, Choudhary P et al. Health-care professional opinions of DIY artificial pancreas systems in the UK. Lancet Diabetes and Endocrinology. 2020; 8(3): 186-187.

Crabtree TSJ, McClay A and Wilmot EG. DIY artificial pancreas systems: here to stay? Practical Diabetes. 2019; 36: 63-68.

Critical Appraisal Skills Programme. CASP (cohort study checklist) checklist 2018. Available at https://casp-uk.b-cdn.net/wp-content/uploads/2018/03/CASP-Cohort-Study-Checklist-2018_fillable_form.pdf. Accessed 2nd January 2022.

Critical Appraisal Skills Programme. CASP (qualitative checklist) checklist 2018. Available at https://casp-uk.b-cdn.net/wp-content/uploads/2018/03/CASP-Qualitative-Checklist-2018_fillable_form.pdf. Accessed 2nd January 2022.

Crocket H. Peer Mentoring in the Do-it-Yourself Artificial Pancreas System Community. Journal of diabetes science and technology. 2020; 14(6): 1022-1027.

Crocket H, Lewis D et al. Learning Challenges of Health Care Professionals Supporting Open-Source Automated Insulin Delivery. Diabetic Medicine. 2021; e14750.

de Bock, Lewis M et al. The CREATE (Community deRivEd AutomaTEd insulin delivery) Trial, available at https://www.otago.ac.nz/christchurch/departments/paediatrics/research/otago717634.html, last accessed 27th January 2022.

Diabetech: Looping. What is it? Available at https://www.diabettech.com/looping-a-guide/what-is-it/, last visited 27th January 2022.

Diabetes Australia. Position Statement: People with Type 1 Diabetes and Do-It-Yourself (DIY) Technology Solutions, available at https://www.diabetesaustralia.com.au/wp-content/uploads/DIY-solution-position-statement.pdf, last accessed 29th January 2022.

Diabetes Canada. Continuous Glucose Monitoring (CGM), available at https://www.diabetes.ca/DiabetesCanadaWebsite/media/Managing-My-Diabetes/Tools%20and%20Resources/Continuous_Glucose_Monitoring_Advocacy_Pkg_4.pdf?ext=.pdf, last accessed 27th January 2022.

Diabetes Canada. Flash Glucose Monitoring, Jan 2020, available at https://www.diabetes.ca/DiabetesCanadaWebsite/media/Managing-My-

Diabetes/Tools%20and%20Resources/Flash_Glucose_Monitoring.pdf, last accessed 27th January 2022.

Diabetes Canada. Coverage of Insulin pumps across Canada, March 2020, available at https://www.diabetes.ca/DiabetesCanadaWebsite/media/Advocacy-and-Policy/Advocacy%20Reports/Insulin-Pumps-Comparison-EN.pdf, last accessed 17th January 2022.

Dowden S and Hudson B. Paris-Brest-Paris: Ultra-endurance cycling with type one diabetes using an open-source artificial pancreas system. ATTD. 2021;P050/30.

Dowling L, Wilmot EG, Choudhary P. Diabetes UK Position Statements. Do-it-yourself closed-loop systems for people living with type 1 diabetes. Diabetic Medicine. 2020: 37: 1977-1980.

Downs MJ, Brennan ML, Williams HC and Dean RS. Development of a critical appraisal tool to assess the quality of cross-sectional studies (AXIS. BMJ Open. 2016; 6 (12).

Duke M and Fredlock A. Do-it-yourself (DIY) systems in diabetes: A family and provider perspective. Journal of Diabetes Science and Technology. 2020. 14 (5):917-921.

El-Laboudi A, Godsland I, Johnson D and Oliver N. Measures of glycemic variability in Type 1 diabetes and the effect of real-time continuous glucose monitoring. Diabetes Technology and Therapeutics. 2016; 18: 806-812.

Elliot J, Jacques RM et al. Substantial reductions in the number of diabetic ketoacidosis and severe hypoglycaemia episodes requiring emergency treatment lead to reduced costs after structured education in adults with type 1 diabetes. Diabetic Medicine. 2014; 31: 847-853.

Evans M, Welsh Z et al. The Impact of Flash Glucose Monitoring on Glycaemic Control as Measured by HbA1c: A Meta-analysis of Clinical Trials and Real-world Observational Studies. Diabetes Therapy. 2020; 11(1): 83-95.

Foster M, Beck R et al. state of Type 1 Diabetes Management and Outcomes from the T1D Exchange in 2016-2018. Diabetes Technology and Therapeutics. 2019; 21(2): 66-72.

Garfinkel J. My life as a practical cyborg: A T1D's reflection on Loop and the DIY bio-hack movement. ATTD. 2020;205/674.

Gawrecki A, Klupa T et al. Utilization of do-it-yourself artificial pancreas systems in the management of patients with type 1 diabetes: a position statement of the Pump School Education Initiative by Diabetes Poland. Polish archives of internal medicine. 2019; 129(2): 141-142.

Gawrecki A, Zozulinska-Zoilkiewicz D et al. Safety and glycemic outcomes of do-it-yourself AndroidAPS hybrid closed-loop system in adults with type 1 diabetes. PLoS One. 2021; 5: 16(4).

General Medical Council. Good Practice in prescribing and managing medicines and devices. 2013; available at https://www.gmc-uk.org/ethical-guidance/ethical-guidance-for-doctors/prescribing-and-managing-medicines-and-devices, last accessed 18th January 2022.

Girelli A, Gariboldi D et al. First Italy DIY APS users survey. ATTD. 2020; 239/800.

Government of Ontario. 1991. Regulated Health Professions Act, 1991. SO 1991, C.18. Retrieved January 6, 2022. <http://www.elaws.gov.on.ca/html/statutes/english/elaws_statutes_91r18_e.htm>.

Harris PA, Taylor R et al. Research electronic data capture (REDCap)- A meta-data driven methodology and workflow process for providing translational research informatics support. J Biomed Inform. 2009. 42(2): 377-81.

Harris PA, Taylor R et al. The REDCap consortium: building an international community of software partners. J biomed Inform. 2019. May 9.

Health Canada. Guidance Document: Software as a Medical Device (SaMD): Classification Examples. 2019. Available at https://www.canada.ca/en/health-canada/services/drugs-health-products/medical-devices/application-information/guidance-documents/software-medical-device-guidance/examples.html#a1, last accessed 29th January 2022.

Heiden Telo G, Schaan de Souza M et al. Comparison between adherence assessments and blood glucose monitoring measures to predict glycemic

control in. adults with type 1 diabetes: a cross-sectional study. Diabetology & Metabolic Syndrome. 2016; 8(54): s13098.

Heinemann L. and Freckmann G. CGM versus FGM; or, continuous glucose monitoring is not flash glucose monitoring. Journal of Diabetes Science Technology. 2015; 9: pp.947-950.

Heinemann L and Lange K. "Do It Yourself" (DIY)—Automated Insulin Delivery (AID) Systems: Current Status from a German Point of View. Journal of Diabetes Science and Technology. 2020; 14(6): 1028-1034.

Heller SR, Gianfrancesco C, Taylor C and Elliott J. What are the characteristics of the best type 1 diabetes patient education programmes (from diagnosis to long-term care), do they improve outcomes and what is required to make them more effective? Diabetic Medicine. 2020; 37(4): 545-554.

Herzog AL, Busch J et al. Survey about do-it-yourself closed loop systems in the treatment of diabetes in Germany. PLoS One. 2020; 15(12): 0243.

Hng TM and Burren D. Appearance of Do-It-Yourself closed-loop systems to manage type 1 diabetes. Internal Medicine Journal. 2018; 14 (11): 1400-1404.

Hollis v. Dow Corning Corp., 1995 CanLII 55 (SCC), [1995] 4 SCR 634, <https://canlii.ca/t/1frdr>, retrieved on 2022-01-30.

Hood K, Wong J et al. Do-it-yourself (DIY) Loop is associated with Psychosocial benefits. Diabetes. 2020;Jun:69(suppl 1).

Imran SA, Agarwal G et al. Diabetes Canada: Targets for Glycemic Control. Chapter 8. Available at https://www.diabetes.ca/health-care-providers/clinical-practice-guidelines/chapter-8#panel-tab_FullText, last accessed 27th January 2022.

INSPIRE questionnaire for adults, available at https://static1.squarespace.com/static/5a138c2df6576e7fb23868e8/t/5f12309765d7c723e00c13be/1595027607811/INSPIRE+Questionnaire+for+Adults+post+assessment+FINAL+VERSION+17th+June+2020.pdf, last accessed 15th February 2022.

JDRF June 2021. Available at https://www.jdrf.ca/two-wins-for-continuous-glucose-monitoring-cgm-devices-in-quebec-and-british-columbia/, last accessed 16th February 2022.

Jennings P and Hussain S. Do-It-Yourself Artificial Pancreas Systems: A Review of the Emerging Evidence and Insights for Healthcare Professionals. Journal of Diabetes Science and Technology. 2019; 14(5): 868-877.

Jeyaventhan R, Gallen G, Choudhary P and Hussain S. A real-word study of user characteristics, safety and efficacy of open-loop closed-source systems and Medtronic 670G. Diabetes, Obesity and Metabolism. 2021. Online ahead of print.

Jiranova P, Soupal J et al. An AndroidAPS Hybrid Closed Loop system in a home setting is safe and leads to better metabolic control. ATTD. 2019; 0270:191.

Johnson C. Good enough? Parental decisions to use DIY looping technology to manage type 1 diabetes in children. Monash Bioethics Review. 2021; July.

Kesavadev J, Saboo B et al. Evolution of Insulin Delivery Devices: From Syringes, Pens and Pumps to DIY Artificial Pancreas. Diabetes Therapy. 2020. 11(6): 1251-1269.

Kesavadev J, Saboo B, Kar P and Sethi J. DIY artificial pancreas: A narrative of the first patient and the physicians' experiences from India. Diabetes & metabolic syndrome. 2021; 15(2): 615-620.

Kesavadev J, Srinivasan S et al. The Do-It-Yourself Artificial Pancreas: A Comprehensive Review. Diabetes Therapy. 2020; 11: 1217-1235.

Kitabchi AE, Umpierrez GE, Murphy MB, et al. Hyperglycemic crises in adult patients with diabetes: A consensus statement from the American Diabetes Association. Diabetes Care 2006; 29:2739–48.

Leelarathna L, Choudhary P et al. Hybrid closed-loop therapy: where are we in 2021? Diabetes, Obesity and Metabolism. 2020; 23(3): 655-660.

Lemieux P, Yamamoto J and Donovan L. Do-It-Yourself Artificial Pancreas System Use in Pregnant Women with Type 1 Diabetes in a Real-World Setting: 2 Case Reports. Canadian Journal of Diabetes. 2021; 20:S1499-2671.

Lewis DM. Automated Insulin Delivery: How artificial pancreas closed-loop systems can aid you living with type 1 diabetes, available at https://diyps.org/2019/06/05/automated-insulin-delivery-how-artificial-

pancreas-closed-loop-systems-can-aid-you-in-living-with-diabetes-introducing-the-aps-book-by-danamlewis/ , last visited 21st February 2022.

Lewis DM. DIYPS: About Dana Lewis, available at https://diyps.org/about/dana-lewis/, last visited 21st February 2022.

Lewis D. History and Perspective on DIY Closed Looping. Journal of Diabetes Science and Technology. 2019; 13(4): 790-793.

Lewis D and Leibrand S. Real-World Use of Open-Source Artificial Pancreas Systems. Journal of Diabetes Science and Technology. 2016; 10(6): 1411.

Lewis D, Swain R and Donner T. Improvements in A1C and Time-in-Range in DIY Closed-Loop (OpenAPS) Users. Diabetes. 2018; 67(suppl 1).

Lind M, Polonsky W et al. continuous Glucose Monitoring vs Conventional Therapy for Glycemic Control in Adults with Type 1 Diabetes Treated with Multiple Daily Insulin Injections: The GOLD Randomized Clinical Trial. JAMA. 2017; 317(4): 379-387.

Litchman M, Lewis D, Kelly L and Gee P. Twitter Analysis of #OpenAPS DIY Artificial Pancreas Technology Use Suggests Improved A1C and Quality of Life. Journal of diabetes science and technology. 2019; 13(2): 164-70.

Litchman M, Walker H et al. Patient-Driven Diabetes Technologies: Sentiment and Personas of the #WeAreNotWaiting and #OpenAPS Movements. Journal of diabetes science and technology. 2020; 14(6): 990-999.

Look H. 99 Years closer: About our FDA submission of Tidepool Loop, available at https://www.tidepool.org/blog/99-years-closer-about-our-fda-submission-of-tidepool-loop, last accessed 23rd February 2022.

LoopDocs, available at https://loopkit.github.io/loopdocs/, last accessed 5th February 2022.

Looped Facebook Group available at www.facebook.com/groups/TheLoppedGroup, last accessed 7th February 2022.

Lum J, Bailey R et al. A Real-World Prospective Study of the Safety and Effectiveness of the Loop Open-Source Automated Insulin Delivery System. Diabetes technology & therapeutics. 2021; 23(5): 367-375.

Lyche, CS. Taking on the completion challenge: A Literature review on policies to prevent dropout and early school leaving. Organization for Economic Co-operation and Development. 2010.

Manning M, Singh H, Stoner K and Habif F. The Development and Psychometric Validation of the Diabetes Impact and Device Satisfaction Scale for Individuals with Type 1 Diabetes. Journal of Diabetes Science and Technology. 2020. 14(2): 309-317.

March C, Oyetoro R et al. School Nurse Perspectives of Do-it-Yourself Artificial Pancreas systems in the School Setting. Diabetes Technology and Therapeutics. 2021. 26; online ahead of print.

Marshall D, Holloway M et al. Do-It-Yourself Artificial Pancreas Systems in Type 1 Diabetes: Perspectives of Two Adult Users, a Caregiver and Three Physicians. Diabetes Therapy. 2019; 10(5):1553-1564.

McGibbon A, Adams L et al. Diabetes Canada 2018 Clinical Practice Guidelines for the Prevention and Management of Diabetes in Canada: Glycemic Management in Adults with Type 1 Diabetes. Canadian Journal of Diabetes. 2018; 42(1): 80-87.

Medtronic announces Health Canada Licence of the Minimed 630G, available at www.medtronic.com/ca-en/about/news/minimed-630G-system.html, last accessed 23rd December 2021.

Melmer A, Zuger T et al. Glycaemic control in individuals with type 1 diabetes using an open-source artificial pancreas system (OpenAPS). Diabetes, obesity & metabolism. 2019; 21(10): 2333- 2337.

Mewes D and Braune K. Qualitative analysis of subjectively perceived glycemic variations and therapy adjustments with respect to the menstrual cycle in girls and women using an open source automated delivery system. Pediatric Diabetes. 2021; 22(S1): EP039.

Murray J, Clayton M and Litchman M. Health Care Provider Knowledge and Perceptions of FDA-Approved and Do-It-Yourself Automated Insulin Delivery. Journal of diabetes science and technology. 2020; 14(6): 1017-1021.

Nathan DM, Genuth S et al. Diabetes Control and Complications Trial Research Group: The effect of intensive treatment of diabetes on the development and

progression of long-term complications in insulin-dependent diabetes mellitus. NEJM. 1993; 329(14): 977-986.

Open APS, available at https://openaps.org, last visited 27th January 2022.

OpenAPS.org, Open APS Outcomes, available at https://openaps.org/outcomes, last accessed 24th January 2022.

Palmer W, Greely S, Letourneau-Frieburg LR, Naylor R. Using a Do-It-Yourself Artificial Pancreas: Perspectives from Patients and Diabetes Providers. Journal of Diabetes science and technology. 2020; 14(5): 860-867.

Patel R, Crabtree TSJ et al. Do-it-yourself artificial pancreas systems (DIY APS): Qualitative analysis of patient's perspectives of quality of life and glucose outcomes. Diabetic Medicine. 2021;38(S1):P225.

Patel R, Crabtree TSJ et al. Glycaemic Outcomes of do-it-yourself artificial pancreas systems (DIY APS) verses Freestyle Libre (FSL) with concomitant insulin pump therapy (CSII): A cross-sectional comparison from the Royal Derby Hospital cohort. Diabetic Medicine. 2021;38(S1):P226.

Patton MA. One year of DIY looping after 38 years of type 1 diabetes Australia Diabetes Educator. 2019; 22(2), available at https://myartificialpancreas.net/2019/07/09/one-year-of-diy-looping-after-38-years-of-type-1-diabetes/, last accessed 4th January 2022.

Petrovski G, Al Khalaf F et al. One-year experience of hybrid closed-loop system in children and adolescents with type 1 diabetes previously treated with multiple daily injections: drivers to successful outcomes. Acta Diabetologica. 2021; 58(2): 207-213.

Petruzelkova L, Jiranova P et al. Pre-school and school-aged children benefit from the switch from a sensor-augmented pump to an AndroidAPS hybrid closed loop: A retrospective analysis. Paediatric Diabetes. 2021; 22(4): 594-604.

Petruzelkova L, Soupal J et al. Excellent Glycemic Control Maintained by Open-Source Hybrid Closed-Loop AndroidAPS During and After Sustained Physical Activity. Diabetes technology & therapeutics. 2018; 20(11): 744-750.

Pickup J, Freeman S and Sutton A. Glycemic control in type 1 diabetes during real time continuous glucose monitoring compared with self-monitoring of blood glucose: meta-analysis of randomised controlled trials using individual patient data. BMJ. 2011; 343: d3805.

Pinsker J, Muller L et al. Real-World Patient Reported Outcomes and Glycemic Results with Initiation of Control IQ Technology. Diabetes technology and therapeutics. 2021; 23(2): 120-127.

Polonsky W, Fisher L et al. Assessing psychosocial distress in diabetes: development of the diabetes distress scale. Diabetes Care. 2005;28:626-631.

Provenzano V, Guastamacchia E, et al. Closing the loop with OpenAPS in people with type 1 diabetes—experience from Italy. Diabetes. 2018;67(suppl 1).

QSR International Pty Ltd. (2020) NVivo (released in March 2020), available at; https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home.

Quintal A, Messier V et al. A Qualitative Study of the Views of Individuals with Type 1 Diabetes on the Ethical Considerations Raised by the Artificial Pancreas. Narrative enquiry in Bioethics. 2020; 10(3).

Racklyeft N. The history of Loop and Loopkit: Reflecting on the past in celebration of version 1.0, available at https://medium.com/@loudnate/the-history-of-loop-and-loopkit-59b3caf13805, last accessed 24th January 2022.

Reddy M, Jugnee M et al. A randomized control pilot study of continuous glucose monitoring and flash glucose monitoring in people with type 1 diabetes and impaired awareness of hypoglycaemia. Diabetic Medicine. 2018; 35(4): 483-490.

Roberts JTF, Moore V and Quigley M. Prescribing Unapproved Medical Devices? The Case of DIY Artificial Pancreas Systems. Medical Law International. 2021.

Roze S, Smith-Palmer J et al. Cost-effectiveness of sensor-augmented pump therapy with low glucose suspend versus standard pump therapy in two different patient populations with type 1 diabetes in France. Diabetes Technology and Therapeutics. 2016; 18: 75-84.

Schipp J, Skinner T et al. How Adults with Type 1 Diabetes Are Navigating the Challenges of Open-Source Artificial Pancreas Systems: A Qualitative Study. Diabetes technology & therapeutics. 2021; 10:1089.

Schipp J, Skinner T et al. 'We're all on the same team'. Perspectives on the future of artificial pancreas systems by adults in Australia with type 1 diabetes using open-source technologies: A qualitative study. Diabetic Medicine. 2021' e14708.

Schutz AK, Schutz-Fuhrmann I et al. Management of type 1 diabetes mellitus using open-source automated insulin delivery during pregnancy: a case series. Diabetes Technology and Therapeutics. 2021. 0.1089/dia.2021.0260.

Schutz-Fuhrmann I, Schutz A et al. Two Subsequent Pregnancies in a Woman with Type 1 Diabetes: Artificial Pancreas Was a Gamechanger. Journal of Diabetes Science and Technology. 2020; 14(5): 972-973.

Shaw D, Crabtree TSJ et al. The DIY Artificial Pancreas system: An Ethical Dilemma for Doctors. Diabetic Medicine. 2020; 37: 1952.

Shepard J, Breton M et al. User and Healthcare Professional Perspectives on Do-It-Yourself Artificial Pancreas Systems: A need for Guidelines. Journal of Diabetes Science and Technology. 2020.

Sherifali D, Berard L et al. Diabetes Canada Clinical Practice Guidelines: Self-Management Education and Support. Canadian Journal of Diabetes. 2018; 42(suppl 1):s36- 41.

Song C, Booth G, Perkins B and Weisman A. Impact of government-funded insulin pump programs on insulin pump use in Canada: a cross-sectional study using the National Diabetes Repository. BMJ Open Diabetes Research & Care. 2021;9:e002371.

Strandberg S, Graue M et al. Longitudinal relationship between diabetes-specific emotional distress and follow-up HbA1c in adults with Type 1 diabetes mellitus. Diabetic Medicine. 2015; 32(10): 1304-1310.

Street TJ. Review of Self-Reported Data from UK Do-It-Yourself Artificial Pancreas System (DIYAPS) Users to Determine Whether Demographic of Population Affects Use or Outcomes. Diabetes Therapy. 2021.

Thabit H, Prabhu J et al. Use of Factory Calibrated Real-time Continuous Glucose Monitoring improves Time in Target and HbA1c in a Multiethnic cohort of Adolescents and Young Adults with type 1 diabetes: The MILLENIAL Study. Diabetes Care. 2020; 14: 42.

The diaTribe Foundation. Health Canada Clears MiniMed770G Automated Insulin Delivery system, available at https://diatribe.org/health-canada-clears-minimed-770g-automated-insulin-delivery-system, last accessed 29th January 2022.

Thomas J and Harden A. Methods for the thematic synthesis of qualitative research in systematic reviews. BMC Medical Research Methodology. 2008; 8: 45.

Tong A, Flemming K, McInnes E, Oliver S, Craig J. Enhancing transparency in reporting the synthesis of qualitative research: ENTREQ. BMC Med Res Meth. 2012;12:181.

Treiber G, Novak E, Hantschel E and Mader J. Challenges with DIY Loop in pregnancy with type one diabetes. ATTD.2021;P278/107.

Vecchio I, Tornalli C et al. The Discovery of Insulin: An Important Milestone in the History of Medicine. Frontiers in Endocrinology. 2018; 9: 613, 1-8.

Von Korff M, Gruman J et al. Collaborative management of chronic illness. Ann Intern Med 1997;127: 1097–1102.
Watts M. Health Law in Canada. Osler. 2014, available at https://www.osler.com/PDFs/Resource/en-ca/Health-Law-in-Canada.pdf, last accessed 29th January 2022.

Waiker AR, Arora T et al. Case Report: Managing Pregnancy with Type 1 Diabetes using a do-it-yourself Artificial Pancreas System. Clinical Diabetes. 2021. Vol 39 (4): 441-444.

Weisman A, Bai JW, Cardinez M, Kramer CK, Perkins BA. Effect of artificial pancreas systems on glycaemic control in patients with type 1 diabetes: a systematic review and meta-analysis of outpatient randomised controlled trials. Lancet Diabetes and Endocrinology. 2017; 5(7): 501- 512.

Weissburg-Benchell J, Shapiro JB at al. Assessing patient-reported outcomes for automated insulin delivery systems: the psychometric properties of the INSPIRE measures. Diabetic Medicine. 2019. 36(5): 644-652.

West R, Michie S. A brief introduction to the COM-B Model of behaviour and the PRIME theory of motivation. Qeios, CC-BY 4.0. April 9, 2020.

White S, Reid A et al. 'Looping' through pregnancy by a woman with type 1 diabetes. Diabetic Medicine. 2020; 37(S1).

Wilmot EG, Langeland L, Mclay A and Taylor N. 1067-P: open source artificial pancreas system (APS) vs. combination insulin pump with flash glucose monitoring in adults with type 1 diabetes: an observational study. Diabetes. 2019;68:1067-P.

Wong J, Suttiratana S. Discontinued use of the Loop Insulin Dosing System: A Mixed-Methods Investigation. Diabetes Technology and Therapeutics. 2021; e0362.

Wu Z, Luo S et al. Use of a do-it-yourself artificial pancreas system is associated with better glucose management and higher quality of life among adults with type 1 diabetes. Therapeutic advances in endocrinology and metabolism. 2020; 25:11: 204.

Wu Z, Luo S et al. Use of do-it-yourself hybrid closed-loop is associated with better glucose management and higher quality of life among adults with type 1 diabetes. ATTD. 2020;267/266.

Yale JF, Paty B and Senior PA. Diabetes Canada Clinical Practice Guidelines Expert Committee: Chapter 14 Hypoglycemia. Available at https://www.diabetes.ca/health-care-providers/clinical-practice-guidelines/chapter-14#panel-tab_FullText, last accessed 28th February 2022.

Yeh H, Brown T et al. Comparative Effectiveness and Safety of Methods of Insulin Delivery and Glucose Monitoring for Diabetes Mellitus: A Systematic review and Meta-Analysis. Annals of Internal Medicine. 2012; 157: 336-347.

Zabinsky J, Buchanan J and Wond J. User perceptions and satisfaction with do-it-yourself closed-loop systems for type 1 diabetes. ATTD. 2020;268/234.

Zabinsky J, Howell H et al. Do-it-yourself artificial pancreas systems for type 1 diabetes reduce hyperglycemia without increasing hypoglycaemia. Diabetes. 2020;Jun;69(suppl 1).

Zoom Video Communications Inc. (2016). Security guide. Zoom Video Communications Inc. available at; https://d24cgw3uvb9a9h.cloudfront.net/static/81625/doc/Zoom-Security-White-Paper.pdf, last accessed 15th February 2022.

Appendices

Figure 2.1.1 Search Strategy

On 31st December 2021

((Automated Insulin Delivery [keyword] OR Loop [keyword] OR Artificial Pancreas [keyword]) AND (DIY [keyword] OR Do it yourself [keyword] OR Do it your-self [keyword] OR open-source [keyword] OR user-driven [keyword] OR community-developed [keyword])

OR

(DIY AID [Title/Abstract] OR DIY APS [Title/Abstract] OR [DIYPS [Title/Abstract]))

AND

(Type 1 diabet* [keyword] OR T1D [keyword])

Table 2.1.1 Study Quality Assessment – Critical Appraisal Skills Program Checklist Qualitative studies [47-55]

Author (Year)	Clear statement of aims	Appropriate methodology	Appropriate research design	Appropriate recruitment strategy	Appropriate data collection methodology	Considered relationship between researcher and participant	Considered ethical issues	Rigorous data analysis	Clear findings
Litchman (2019)	Yes	Yes	Yes	Yes	Yes	Can't tell	Yes	Yes	Yes
Quintal (2020)	Yes	Yes	Yes	No	Yes	Can't tell	Yes	Yes	Yes
Crocket (2020)	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Litchman (2020)	Yes	Yes	Yes	Yes	Yes	Can't tell	Yes	Yes	Yes
Shepard (2020)	Ye	Yes	Yes	Yes	Can't tell	Can't tell	No	No	Yes
Schipp (2021)	Yes	Yes	Yes	Yes	Yes	Can't tell	Yes	Yes	Yes
Crocket (2021)	Yes	Yes	Yes	Yes	Yes	Can't tell	Yes	Yes	Yes
Schipp (2021)	Yes	Yes	Yes	Yes	Yes	Can't tell	Yes	Yes	Yes
Wong (2021)	Yes	Yes	Yes	Yes	Yes	Can't tell	Yes	Yes	Yes

Table 2.1.2 Study Quality Assessment – Critical Appraisal Skills Program Checklist Cohort studies [31, 33-35, 40-44]

Author (Year)	Clear statement of aims	Appropriate recruitment	Accurate measurement of exposure	Accurate measurement of outcome	Confounders: a) Identification b) Consideration in analysis	Follow-up: a) complete b) duration	Appropriate results	Results applicable to local population	Results consistent with existing evidence	Clear implications for practice
Lewis (2016)	Yes	Yes	Yes	Can't tell	a) no b) no	a) can't tell b) can't tell	Yes	Can't tell	Can't tell	Can't tell
Petruzelkova (2018)	Yes	Yes	Yes	Yes	a) yes c) no	a) yes b) can't tell	Yes	Yes	Yes	Yes
Melmer (2019)	Yes	Yes	Yes	Yes	a) no b) no	a) can't tell b) can't tell	Yes	Can't tell	Yes	Can't tell
Braune (2019)	Yes	Yes	Yes	Yes	a) yes b) no	a) yes b) can't tell	Yes	Yes	Yes	Can't tell
Wu (2020)	Yes	Yes	Yes	Yes	a) yes b) no	a) yes b) yes	Yes	Yes	Yes	Yes
Lum (2021)	Yes	Yes	Yes	Yes	a) yes b) no	a) yes b) yes	Yes	Yes	Yes	Yes
Petruzelkova (2021)	Yes	Yes	Yes	Yes	a) yes b) no	a) yes b) yes	Yes	Yes	Yes	Yes
Gawrecki (2021)	Yes	Yes	Yes	Yes	a) yes b) no	a) yes b) yes	Yes	Yes	Yes	Yes
Jeyaventhan (2021)	Yes	Yes	Yes	Yes	a) no b) no	a) yes b) yes	Yes	Yes	Yes	Yes

Table 2.1.3 Study quality Assessment – Appraisal Tool for Cross-sectional Studies (AXIS) [4,32,36-39,45,46]

Author (Year)	Clear aims	Study design, sample, target pop.	Risk factor and outcome variables	Statistical methods described	Description of data	Response bias considered	Justified Discussion	Other incl. ethical approval
Hng (2018)	Yes	Yes	Yes	No	Yes	Yes	Yes	Don't know
Murray (2020)	Yes	Yes	Yes	Yes	Yes	Don't know	Yes	Yes
Crabtree (2020)	Yes	Yes	Yes	No	Yes	Don't know	Yes	Don't know
Palmer (2020)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Don't know
Herzog (2020)	Yes	Yes	Yes	Yes	Yes	Don't know	Yes	Yes
March (2021)	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Braune (2021)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Street (2021)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No

Table 2.1.4 Enhancing Transparency in Reporting the Synthesis of Qualitative Research (ENTREQ) Statement

No.	Item	Description
1	Aim	A review of the currently available literature surrounding DIY AID systems, specifically to highlight the current evidence to support their use.
2	Synthesis methodology	Thematic synthesis due to variety of study methodologies with similar outcomes assessed
3	Approach to searching	Comprehensive search strategy (fig 2.1.1) to identify all relevant publications published studies and conference abstracts
4	Inclusion criteria	Studies published in English, relating to the use of DIY AID systems, qualitative, cross-sectional and cohort
5	Data sources	Embase, Medline, Web of Science, Scopus, Cochrane library, Proquest, conference abstracts ADA, DUK, ATTD last 2 years.
6	Electronic search strategy	Figure 2.1.1 - search strategy performed on 31st December 2021
7	Study screening methods	Two independent reviewers (AM and KC), screening by title, abstract and full text (figure 2.1- PRISMA flowchart) with independent third reviewer (AL) to resolve any debated studies for inclusion.
8	Study characteristics	Table 2.1 – study characteristics case control studies Table 2.2 - study characteristics cohort studies Table 2.3- study characteristics qualitative studies Table 2.1.5 (appendices)- study characteristics conference abstracts
9	Study selection results	See figure 2.1 PRISMA Flowchart
10	Rationale for appraisal	Study quality assessment; critical appraisal skills program checklist for both qualitative and quantitative studies (CASP), appraisal tool for cross-sectional studies (AXIS).
11	Appraisal items	Study design, data analysis and reporting presented as study characteristics in table 2.1, 2.2, 2.3, and table 2.1.5 appendices.
12	Appraisal process	Appraisal process performed by one independent author (AM)
13	Appraisal results	Study quality assessment; Appendices table 2.1.1, table 2.1.2 and table 2.1.3.

14	Data extraction	Outcomes and results were manually extracted from the studies after reading the full text and summarized in table 2.1, table 2.2, table 2.3 and table 2.1.5 (appendices).
15	Software	N/A
16	No. of reviewers	Analysis of studies performed by two independent reviewers (AM and KC), with third reviewer (AL) for any disputes in inclusion.
17	Coding	Study results were analyzed line by line to search for common themes or concepts
18	Study comparison	Studies were compared in participants, methods, outcomes and results
19	Derivation of themes	Deriving the themes was an inductive method, using the study outcomes to derive discussion themes due to the limited quantity of existing research in this field
20	Quotations	DIY AID system users, community members and HCPs provided quotations in the form of open-response survey questions and semi-structured interviews.
21	Synthesis output	Discussions and conclusions of this manuscript

First Author (Year)	Country (Format)	System (Study type)	Participants	Outcomes	Results
Lewis (2018)	USA (ADA abstract)	OpenAPS (Retrospective cross-over)	20 OpenAPS users, 4-6 weeks before and after OpenAPS. Mean age 30.2 yr, mean diabetes duration 18.4 yr	With OpenAPS use; Mean blood glucose TIR TAR TBR HbA1c	(vs pre-OpenAPS) 128.3 vs 135.7 mg/dL 82.2 vs 75.8% 13.3 vs 18.3% 4.5 vs 6.0% 6.1 vs 6.4%
Choi (2018)	Korea (Annual Diabetes Technology Meeting abstract)	OpenAPS (Retrospective)	10 OpenAPS users; median age 9.5yrs, 5 male, median duration OpenAPS 30 days,	With OpenAPS use; HbA1c TIR TAR TBR	(vs pre-OpenAPS) 6.2 vs 6.8% 82.8 vs 65.1% 12.3 vs 24.5% 4.9 vs 5.4%
Choi (2018)	Korea (ADA abstract)	OpenAPS (Retrospective)	20 people with T1DM (50% male), mean age 11.9 yrs. Mean duration OpenAPS 120 days (30-240)	With OpenAPS use; HbA1c TIR TAR TBR	(vs pre-OpenAPS) 6.3 vs 6.8% 83.3 vs 70.1% 13.3 vs 24.7% 3.4 vs 5.1%
Provenzano (2018)	Italy (ADA abstract)	OpenAPS (Retrospective)	30 people with T1DM (19 male, 11 female), mean age 35.9 years. Self-report data pre and post 3 months OpenAPS	With OpenAPS use; HbA1c TBR Safety	(vs pre-OpenAPS) 6.61 vs 7.17% 2.48 vs 8.55% No serious AE reported
Braune (2019)	Germany (ADA abstract)	OpenAPS, AndroidAPS, Loop (Cross-sectional)	Online survey, 1058 participants; 80.2% adult users with median age 41 years, 19.8% caregivers for children with T1DM.	With DIY AID use; HbA1c TIR Cost of DIY (out of pocket)/yr Motivations for using a DIY AID system.	(vs pre-DIY) 6.24 vs 7.07% 83.07 vs 63.21% 712 USD Improved glycemic control, need for 'auto-pilot', less complications, better sleep for caregivers.

Wilmot (2019)	UK (ADA abstract)	OpenAPS (Retrospective)	Comparison 9 users OpenAPS; mean age 44.2, diabetes duration 25yrs, OpenAPS 11months, with 30 Freestyle Libre+CSII users, mean age 59.3, diabetes duration 26yrs, 5.9 months FSL+CSII.	With OpenAPS use; HbA1c pre OpenAPS use HbA1c TIR TBR Safety	(vs CSII and Freestyle Libre users) 7.3 vs 7.6% 6.2 vs 7.2% 83.6 vs 55.9% 2.5 vs 5.7% No hospital admission or SH in either group
Jiranova (2019)	Czech Republic (ATTD abstract)	AndroidAPS (Retrospective cohort)	22 children; age 3-14 years, mean duration AndroidAPS 8.7months, at least 3 months of AndroidAPS was compared to the preceding 3 months of SAP in these participants.	With AndroidAPS use; HbA1c TIR TBR	(vs SAP) 47 vs 52 mmol/mol 83.6 vs 67.6% 4.4 vs 5.2%
Zabinsky (2020)	USA (ADA abstract)	OpenAPS, AndroidAPS, Loop (Retrospective)	DIY group; 74 individuals, 90 days of data, mean age 36 and diabetes duration 24 years, with 98 age matched SAP participants.	With DIY AID use; TBR hypoglycemic episodes per month, <54mg/dL Mean glucose TAR TIR	(vs SAP) 3.8 vs 4.7% 32.9 vs 33.4 episodes 0.8 vs 1.3% 134.9 vs 150.3 mg/dL 16.9 vs 26.1% 79.3 vs 69.2%
Hood (2020)	USA (ADA abstract)	Loop (Prospective)	254 new loop users recruiting through online posting and Loop RileyLink packaging, mean age 38.4 years, HbA1c 6.64%, TIR 69.6%.	PRO surveys at 3 months; Diabetes Distress Scale Technology attitudes Fear of hypoglycaemia Hypoglycaemia confidence Technology problem solving Pittsburgh sleep quality inventory.	(vs baseline) 1.66 vs 2.06 20.21 vs 20.11 17.18 vs 19.74 29.91 vs 27.21 29.36 vs 28.7 5.39 vs 6.82

Zabinsky (2020)	USA (ATTD abstract)	OpenAPS, AndroidAPS, Loop (Cross-sectional)	180 DIY AID users, mean age 34 yrs, duration DM 20 yrs.	Self-reported outcomes with DIY AID; Reduction in hypoglycaemia Reduction in hyperglycemia Increased sleep quality/quantity Reduced time spent managing diabetes Reduced diabetes related stress Satisfied with o/n BG Dissatisfaction with set up Troubleshooting	 86.5% 87.6% 74.7% 69.4% 76.9% 97.6% 19.9% 19.3%
Wu (2020)	China (ATTD abstract)	AndroidAPS (Retrospective)	10 participants with >3months AndroidAPS use; 6 female, median age 34.1yrs, diabetes duration 13 yrs, HbA1c 7.3%	With 3months AndroidAPS use; HbA1c TIR	(vs pre-DIY) 6.53 vs 7.37% 84.75 vs 76.30% Less hypoglycaemia and lower fear of hypoglycaemia with AndroidAPS use.
Garfinkel (2020)	Canada (ATTD abstract/ PhD thesis)	Loop (Case report)	Case study of an individual living in 2019 with T1DM on Loop.	Diary/literary memoir of experiences.	Opening possibility of broader empathy, the 'second person perspective'
Girelli (2020)	Italy (ATTD abstract)	OpenAPS (2 users), AndroidAPS (n=8), Loop (n=9) (Cross-sectional)	Online survey via the Looped and OpenAPS Facebook groups. Respondents; 120 interested in DIY AID and 19 users, mean age 28.1 yrs.	Type of pump used. Reasons for planning DIY AID. Clinic response to plans.	Omnipod (50%), AccuChek (25%), Medtronic (15%), Tandem (5%), Dana (5%). Improve control, sleep better, more discrete system, reduce hypoglycaemia. 60% positive
White (2020)	UK (Diabetes UK abstract)	Loop (Case report)	37yr F with 22yr history of T1DM, started looping eight months prior	With Loop use; Preconception HbA1c Final pregnancy HbA1c	(vs CSII and CGM) 6.2 vs 6% 5.3 vs 5.5%

			to 2nd pregnancy (1st pregnancy CSII and CGM)	Delivery type and timing Birth weight	C-section 38+4 vs normal 38+4 wk 3.53 vs 3.79kg
Patel (2021)	UK (Diabetes UK abstract)	OpenAPS, AndroidAPS, Loop (Retrospective)	17 patients using DIY AID and 149 using CSII with Freestyle Libre, with minimum 1 month therapy	With DIY AID use; HbA1c TIR TBR TAR	(vs CSII and Freestyle Libre users) 47.2 vs 60.1 mmol/mol 77.6 vs 52.8% 2.5 vs 5.7% 18.8 vs 41.7%
Patel (2021)	UK (Diabetes UK abstract)	OpenAPS, AndroidAPS, Loop (Qualitative)	17 patients using DIY AID, mean age 43 yrs.	Free-text feedback on the use of the technology and review of patient records for patient opinions or comments	Themes identified; general quality of life (QOL), diabetes related QOL, technological problems, perception of improved diabetes control
Mewes (2021)	Germany (Abstract IS Paediatric and Adolescent Diabetes)	OpenAPS, AndroidAPS, Loop (Qualitative)	11 girls and women recruited through topic related discussion groups on social media; 1 during pregnancy, 1 puberty and 3 menopause.	Semi-structured interviews, focused on perceived changes, therapy adjustments, and suggestions for AID optimization.	All noted glycemic variability with menstrual cycle, concerns over algorithm adjustment due to individual nature of hormone activity.
Cohen (2021)	UK (ATTD abstract)	OpenAPS, AndroidAPS, Loop (Qualitative)	20 HCPs from pediatric and adult diabetes services, interviewed on perceptions of DIY AID benefits and barriers to its use.	Reported benefits; Improved glycemic outcomes No added risk compared to other diabetes tech Customizability Barriers; Liability concerns Lack of formal guidelines	 n=13 n=12 n=9 n=19 n=19
Dowden (2021)	UK (ATTD abstract)	AndroidAPS (Case report)	37 yr female completing 1200km PBP cycle using AndroidAPS.	Cycle completed TIR TAR TBR <3.5mmol/L, lowest glucose Mean glucose	89 hrs 28mins 58% 38% 4% <1%, 3.1mmol/L 9.7mmol/L

Cohen (2021)	UK (ATTD abstract)	OpenAPS and AndroidAPS (Qualitative)	Semi-structured interviews with 26 adults and 14 parents of youth (<18yrs) using DIY AID.	Benefits for adults Benefits for parents Shortcomings for adults Shortcoming for parents HCP support	Glycemic (n=26), overnight management (n=26), reduced burden diabetes (n=23) Overnight (n=12), glycemic (n=11), exercise (n=10) Independent set up (n=23), system only as good as components (n=18), insurance (n=18) Set up (n=10), components (n=10), connectivity (n=6) Majority supportive
Alidibbiat (2021)	Kuwait (ATTD abstract)	Loop (n=3) and AndroidAPS (n=2) and CamAPS (n=1) (Case series)	5 DIY and one commercial AID user, mean age 33.7yrs, diabetes duration 23.5 yrs, BMI 23.6, HbA1c 6.3%.	DIY AID use during Ramadan; Mean glucose Coefficient of Variability TIR TBR Days fasted Days fast broken due to diabetes	 7.0mmol/L 28.5% 88.8% 2.5% 27.3 days 1 day
Treiber (2021)	Austria (ATTD abstract)	Loop (Case report)	32-year female with 16-year history of diabetes, using Loop during pregnancy, complicated by hyperemesis.	With Loop use; HbA1c TM 1/2/3 TIR (70-140mg/dL) TDD insulin TM 1/2/3 Delivery type Birth weight, Timing, APGAR.	 32/24/31mmol/mol 75-82% 28/41/61 IU C-section 3590g, 40+3 weeks 9/10/10. Noted CGM inaccuracy with HG and dehydration.

Table 2.1.5 DIY AID Conference Abstracts [56-77]

Figure 3.1.1 HCP Survey Full Text

HCP Attitudes towards Automated Insulin Delivery

Thank you for taking this 20-minute, anonymous survey. Your name will not be recorded anywhere in this survey. You may choose not to answer any questions you don't want to answer, by selecting the option prefer not to say or n/a.

About the researchers: This survey is part of a study led by Dr Anna Lam and Dr Peter Senior, both endocrinologists and researchers at the University of Alberta, specializing in type 1 diabetes management and currently looking after patients with type 1 diabetes using Automated Insulin Delivery systems (AID). Helping us with the project are Dr Holly Witteman and Olivia Drescher, researchers from Laval University; and a patient partner from Diabetes Action Canada, Kate Farnsworth, who runs the Looped Facebook group.

We are also collaborating with colleagues in the UK; Dr Emma Wilmot and Dr Tom Crabtree, who conducted a brief HCP survey in 2019 (Crabtree T, Choudhary P et al. Health-care Professional Opinions of DIY Artificial Pancreas Systems in the UK. Lancet Diabetes and Endocrinology.2020;8(3):186-187).

Purpose of the study: The purpose of this study is to understand the current knowledge, experience and attitudes of healthcare providers across Canada in the use of Automated Insulin Delivery systems (AID) in patients with type 1 diabetes. Questions relate to the use of Commercial AID; Hybrid Closed Loop systems (Medtronic 670G or 770G and Tandem Control IQ), as well as DIY AID systems; AndroidAPS, OpenAPS and Loop. We aim to identify areas of knowledge gaps and concern, to enable targeted education with the aim of improved patient care for those using these systems.

Your participation: Participating in this study will involve answering a 20-minute survey, with 31 questions, on your current experience, knowledge and attitudes towards AID systems.

Eligibility:

You may participate in this study if:

You are a healthcare provider licensed in Canada. You look after patients with type 1 diabetes as part of your professional role; including physicians, nurses, dietitians and educators. You are able to read and understand this page. Risks and benefits: There are no personal risks or benefits to answering the survey. Your answers may help guide future education in the area of AID systems and therefore improved patient care for people living with type 1 diabetes and using these systems.

Confidentiality and data protection: All information we collect will be confidential and used only for research purposes. Data will be collected and stored on secure servers located in Canada, it will be anonymous, with no identifiable information. When we work with data, the only people who will have access to the data will be the investigators in our research team, who have completed relevant ethics training. When the data is stored on our computers, each computer will be secure and password protected.

After the end of the study: Only anonymous, non-identifiable data will be stored. Data will be kept securely, in line with the University of Alberta Ethics regulations, for a minimum of five years.

Contacts: If you have any questions about the research study, or if you experience a problem as a result of participating in the study, please contact:

Dr Anna Lam

Department of Medicine, University of Alberta

Email: alam5@ualberta.ca

Consent: By answering the questions in this survey, you are indicating your consent to have your answers used in this study. If you do not want to participate in the study, please do not answer the questions.

This study has been approved by the Research Ethics Committee of University of Alberta, Research Ethics ID; Pro00108472.

Healthcare provider and practice characteristics

1. Are you a healthcare provider licensed to practice in Canada?
- ◯ Yes
- ◯ No

Thank-you for your interest but this survey is restricted to HCP licensed to practice in Canada

2. Do you provide care for adults or children with type 1 diabetes?
- ◯ Adults
- ◯ Children
- ◯ Both
- ◯ Neither

Thank-you for your interest but this survey is restricted to HCPs looking after people with type 1 diabetes

3. Where do you practice?
- ◯ Alberta
- ◯ British Columbia
- ◯ Manitoba
- ◯ New Brunswick
- ◯ Newfoundland and Labrador
- ◯ Northwest Territories
- ◯ Nova Scotia
- ◯ Nunavut
- ◯ Ontario
- ◯ Prince Edward Island
- ◯ Quebec
- ◯ Saskatchewan
- ◯ Yukon
- ◯ Prefer not to say

4. Which setting best describes your clinical practice?
- ◯ Academic centre
- ◯ Urban hospital
- ◯ Rural hospital
- ◯ Community- urban
- ◯ Community - rural
- ◯ Prefer not to say

5. What kind of practitioner are you?
- ◯ MD Endocrinology
- ◯ MD Internal Medicine
- ◯ MD Family Medicine
- ◯ MD other
- ◯ RN
- ◯ RD
- ◯ Pharmacist
- ◯ Prefer not to say

6. Are you a designated CDE?
- ◯ Yes
- ◯ No
- ◯ Prefer not to say

7. How long have you worked with people with diabetes for? (years)
- ◯ < 1
- ◯ 1-5
- ◯ 6-10
- ◯ 11-20
- ◯ >20
- ◯ Prefer not to say

8. a) Do you practice individually or as part of a diabetes clinic/program?
- ☐ Individually
- ☐ Part of diabetes clinic/program
- ☐ Prefer not to say

8. b) Questions 9-11 and 14-15 will relate to patient numbers in your current practice, do you wish to answer these based on your individual practice or those of your diabetes clinic/program?	◯ Individual practice ◯ Diabetes clinic/program ◯ Prefer not to say
9. Roughly, how many of your patients have type 1 diabetes?	◯ < 10 ◯ 10-50 ◯ 51-100 ◯ 101-500 ◯ >500 ◯ Don't know
10. What proportion of your patients with type 1 diabetes use insulin pumps?	◯ < 5% ◯ 5-24% ◯ 25-49% ◯ 50-75% ◯ >75% ◯ Don't know
11. What proportion of your patients with type 1 diabetes use Flash (Freestyle Libre) or Continuous Glucose Monitoring (CGM)?	◯ < 5% ◯ 5-24% ◯ 25-49% ◯ 50-75% ◯ >75% ◯ Don't know
12. How comfortable do you feel supporting your patients that are using insulin pumps?	◯ not at all ◯ somewhat uncomfortable ◯ neither comfortable or uncomfortable ◯ comfortable ◯ very comfortable ◯ n/a
13. How comfortable do you feel supporting your patients that are using Flash (Freestyle Libre) or Continuous Glucose Monitors (CGM)?	◯ not at all ◯ somewhat uncomfortable ◯ neither comfortable or uncomfortable ◯ comfortable ◯ very comfortable ◯ n/a

Healthcare provider current experience and attitudes towards Automated Insulin Delivery (AID)

14. How many of your patients are using Commercial AID systems (Hybrid Closed Loop such as Medtronic 670G, Tandem Control IQ)	◯ None ◯ 1-5 ◯ 6-24 ◯ 25-50 ◯ 51-100 ◯ >100 ◯ Don't know
15. How many of your patients, that you are aware of, are using Do-it-Yourself (DIY) AID systems (eg Loop, Open APS, Android APS)?	◯ None ◯ 1-5 ◯ 6-14 ◯ 15-24 ◯ 25-50 ◯ >50 ◯ Don't know
16. How comfortable do you feel supporting your patients with Commercial AID systems?	◯ not at all ◯ somewhat uncomfortable ◯ neither comfortable or uncomfortable ◯ comfortable ◯ very comfortable ◯ n/a
17. How comfortable do you feel supporting your patients with DIY AID systems?	◯ not at all ◯ somewhat uncomfortable ◯ neither comfortable or uncomfortable ◯ comfortable ◯ very comfortable ◯ n/a
18. Do you initiate discussions about DIY AID as a treatment option in your consultations?	◯ never ◯ rarely ◯ sometimes ◯ frequently ◯ always ◯ n/a
19. Compared with other diabetes professionals, how supportive of DIY AID technology do you think you are?	◯ much less ◯ slightly less ◯ about the same ◯ slightly more ◯ much more ◯ unsure

Barriers to AID use

20. For a patient considering Commercial or DIY AID systems, which are you more likely to recommend?	◯ Commercial ◯ DIY ◯ Either ◯ Neither ◯ Unsure ◯ N/A ◯ Other
If recommending other system, please highlight what this would be?	_____

20 a). For COMMERCIAL AID systems, to what extent do you agree that the following act as barriers for you recommending these systems?

	strongly disagree	disagree	neutral	agree	strongly agree	n/a
You are unfamiliar with/lack exposure to AID systems	○	○	○	○	○	○
Too time consuming	○	○	○	○	○	○
Few options for officially approved devices	○	○	○	○	○	○
Reliability of the system	○	○	○	○	○	○
Medico-legal risks	○	○	○	○	○	○
Lack of high-quality published data	○	○	○	○	○	○
Patient technological skill	○	○	○	○	○	○
Patient literacy and numeracy	○	○	○	○	○	○
Funding/coverage for pumps	○	○	○	○	○	○
Funding/coverage for sensors	○	○	○	○	○	○
Lack of access to staff with AID training	○	○	○	○	○	○

20 b). For DIY AID systems to what extent do you agree that the following act as barriers for you recommending these systems?

(Please rank these factors using options strongly disagree to strongly agree, or n/a)

	Strongly disagree	disagree	neutral	agree	strongly agree	n/a
You are unfamiliar with/ lack exposure to DIY AID systems	◯	◯	◯	◯	◯	◯
Too time consuming	◯	◯	◯	◯	◯	◯
Lack of official approval of devices/systems	◯	◯	◯	◯	◯	◯
Reliability of the system	◯	◯	◯	◯	◯	◯
Medico-legal risks	◯	◯	◯	◯	◯	◯
Lack of high quality published data	◯	◯	◯	◯	◯	◯
Patient technological skill	◯	◯	◯	◯	◯	◯
Patient literacy and numeracy	◯	◯	◯	◯	◯	◯
Funding/coverage for pumps	◯	◯	◯	◯	◯	◯
Funding/coverage for sensors	◯	◯	◯	◯	◯	◯
Lack of access to staff with DIY AID training	◯	◯	◯	◯	◯	◯

21. Are you aware of any of your patients having stopped using AID systems?

◯ Yes
◯ No
◯ Unsure

21. a) If so, what reasons did they give for stopping?

_____

AID Scenarios

In some of the following scenarios (Q24/25, Q26/27, Q30/31) we will ask you to firstly answer relating to COMMERCIAL AID systems (eg Medtronic 670G, Tandem Control IQ) and then relating to DIY AID systems (OpenAPS, AndroidAPS and Loop).

22. If a patient or patient family member asked you whether you would support their decision to START using a DIY AID system, to what extent would you support/encourage them?

- ◯ definitely not
- ◯ probably not
- ◯ neither encourage or discourage
- ◯ possibly yes
- ◯ definitely yes
- ◯ n/a

23. If a patient (or family) HAS STARTED using DIY AID on their own, which aspects of the following support would you provide them with?

	definitely not	probably not	unsure	yes possibly	yes definitely	n/a
Facilitate Prescriptions for hardware (pumps/sensors)	○	○	○	○	○	○
Facilitate Prescriptions for insulin and pump supplies	○	○	○	○	○	○
Facilitate Prescriptions for insulin only	○	○	○	○	○	○
Active support - help with pump settings and adjustments	○	○	○	○	○	○
Passive support- direct to online/other resources	○	○	○	○	○	○
On-going support only for general diabetes care	○	○	○	○	○	○
No on-going support - refer to another diabetes clinic/provider	○	○	○	○	○	○

24. When considering COMMERCIAL AID systems, how important do you think the following factors are in determining whether you would consider a patient 'suitable' for these systems? Please rank from not at all to very important, or n/a.

	not at all	not very	unsure	somewhat important	very important	n/a
HbA1c at or close to target	○	○	○	○	○	○
History of severe hypoglycemia	○	○	○	○	○	○
Hypoglycemia unawareness	○	○	○	○	○	○
Skilled at carbohydrate counting	○	○	○	○	○	○
Current pump user	○	○	○	○	○	○
Monitors glucose levels regularly and reliably	○	○	○	○	○	○
Has coverage/funding for pumps and sensors	○	○	○	○	○	○
Educational level/cognitive abilities	○	○	○	○	○	○
Family resources/social support	○	○	○	○	○	○

25. When considering DIY AID systems, how important do you think the following factors arein determining whether you would consider a patient 'suitable' for DIY AID?

Please rank from not at all to very important, or n/a.

	not at all	not very	unsure	somewhat important	very important	n/a
HbA1c at or close to target	○	○	○	○	○	○
History of severe hypoglycemia	○	○	○	○	○	○
Hypoglycemia unawareness	○	○	○	○	○	○
Skilled at carbohydrate counting	○	○	○	○	○	○
Current pump user	○	○	○	○	○	○
Monitors glucose levels regularly and reliably	○	○	○	○	○	○
Has coverage/funding for pumps and sensors	○	○	○	○	○	○
Educational level/cognitive abilities	○	○	○	○	○	○
Family resources/social support	○	○	○	○	○	○

26. When starting a COMMERCIAL AID system, how comfortable or concerned would you be about an individual starting Commercial AID in the following scenarios?

Please rank very concerned to very comfortable, or n/a.

	very concerned	slightly concerned	neither concerned or comfortable	somewhat comfortable	very comfortable	n/a
Unexplained episode of DKA in the last 12 months	○	○	○	○	○	○
HbA1c at or close to target in current pump user	○	○	○	○	○	○
HbA1c consistently >10%	○	○	○	○	○	○
Infrequent glucose monitoring	○	○	○	○	○	○
Erratic schedule/meal pattern	○	○	○	○	○	○
Evidence of depression and/or diabetes related distress	○	○	○	○	○	○
Obsessive compulsive tendencies	○	○	○	○	○	○
Not using bolus calculator - no set insulin: carb, or insulin sensitivity factor	○	○	○	○	○	○

27. When commencing a DIY AID system, how comfortable or concerned would you be about an individual starting DIY AID in the following scenarios?

Please rank from very concerned to very comfortable, or n/a.

	very concerned	slightly concerned	neither concerned or comfortable	somewhat comfortable	very comfortable	n/a
Unexplained episode of DKA in the last 12 months	◯	◯	◯	◯	◯	◯
HbA1c at or close to target in current pump user	◯	◯	◯	◯	◯	◯
HbA1c consistently >10%	◯	◯	◯	◯	◯	◯
Infrequent glucose monitoring	◯	◯	◯	◯	◯	◯
Erratic schedule/meal pattern	◯	◯	◯	◯	◯	◯
Evidence of depression and/or diabetes related distress	◯	◯	◯	◯	◯	◯
Obsessive compulsive tendencies	◯	◯	◯	◯	◯	◯
No bolus calculator - no set insulin: carb, or insulin sensitivity factor	◯	◯	◯	◯	◯	◯

28. Are there any other factors that you would consider to be important/essential prerequisites for AID use?

◯ Yes
◯ No
◯ Unsure

If yes, what would these be?

_____

If no, why is this?

_____

If unsure, why is this?

_____

29. Do you consider yourself to be actively involved in the care of patients using DIY AID systems?

◯ Yes
◯ No
◯ Unsure

29. a) When you review your patient who is using DIY AID do you review their blood glucose data through the specific app they are using (xDrip, Glimp, Spike etc)?

◯ never
◯ rarely
◯ sometimes
◯ frequently
◯ always
◯ n/a

29. b) How comfortable do you feel in doing this?

◯ not at all
◯ somewhat uncomfortable
◯ neither comfortable or uncomfortable
◯ comfortable
◯ very comfortable
◯ n/a

29. c) If your patient is using DIY AID, do you discuss with them any suggestions for alterations to their settings?	◯ never ◯ rarely ◯ sometimes ◯ frequently ◯ always ◯ n/a
29. d) How comfortable do you feel in doing this?	◯ not at all ◯ somewhat uncomfortable ◯ neither comfortable or uncomfortable ◯ comfortable ◯ very comfortable ◯ n/a
29. e) If your patient is using DIY AID, do you discuss with them any specific support platforms (social media, online communities) they are using?	◯ never ◯ rarely ◯ sometimes ◯ frequently ◯ always ◯ n/a
29. f) How comfortable do you feel in doing this?	◯ not at all ◯ somewhat uncomfortable ◯ neither comfortable or uncomfortable ◯ comfortable ◯ very comfortable ◯ n/a

30. How much would the following make you more confident to recommend and support a patient using a COMMERCIAL AID system?

Please rank from not at all to yes definitely, or n/a.

	not at all	probably not	unsure	yes possibly	yes definitely	n/a
Clinical Practice Guidelines from Diabetes Canada	○	○	○	○	○	○
An educational program for users	○	○	○	○	○	○
Educational program for HCPs	○	○	○	○	○	○
Support for the USER from a certified HCP	○	○	○	○	○	○
Support for YOU from a certified HCP	○	○	○	○	○	○
Medico-legal guidance (eg consent forms, checklist, waivers)	○	○	○	○	○	○

Are there any other suggestions that would make you more confident to recommend and support a patient using a Commercial AID system? _____

31. How much would the following make you more confident to recommend and support a patient using DIY AID system?

	not at all definitely	probably not n/a	unsure	yes possibly	yes
Clinical Practice Guidelines from Diabetes Canada	○	○	○	○	
An educational program for users	○	○	○	○	
An educational program for HCPs					
Support for the USER from a certified HCP	○	○	○	○	
Support for YOU from a certified HCP	○	○	○	○	
Medico-legal guidance (eg consent forms, checklist, waivers)	○	○	○	○	

Are there any other suggestions that would make you more confident to recommend and support a patient using a DIY AID system?

Figure 4.1.1 Interview guide

Edmonton Do-It-Yourself Automated Insulin Delivery (DIY AID) Systems Users

Data Collection Tool

Thank-you for agreeing to take part in this study, the data we will record will remain anonymous and will only be accessible to our study team. You do not have to take part in all parts of this study, if there are any questions you do not wish to answer you do not have to do so.

Demographic Data

1. Age
2. Gender
3. Ethnicity
4. Occupation
5. Highest level of educational attainment
6. Duration of Diabetes (date of diagnosis)
7. Duration of DIY AID use (date commenced)

Commencing DIY AID

1. Type of AID used
2. Method of insulin delivery prior to commencing DIY
3. What was the main reason for you to commence DIY AID?

4. What support did you get in doing so?

5. What were the main challenges that you had to overcome in commencing DIY AID?

6. Can you remember what your last HbA1c was prior to commencing DIY AID?

7. Would you be happy for the research team to review your glucose data prior to commencing DIY AID? (HbA1c/CGM)

8. Would you be happy for the research team to review your glucose data for the last 6 months with DIY AID use? (HbA1c/CGM)

9. What is your daily insulin requirement currently?

10. Can you remember what this was before commencing DIY AID?

Safety of DIY AID

1. Do you feel that DIY AID systems are safe?

2. Have you had any episodes of severe hypoglycemia since commencing DIY AID? If so, when and why did this occur?

3. Since using DIY AID have you had any episodes of DKA? If so, when and why did this occur?

4. Have you required admission to hospital for any other reason since commencing DIY AID?

5. Have you had any episodes of pump failure?

Barriers to DIY AID Use

1. What have you found to be the main barriers in using DIY AID?

2. Do you feel that you have you received adequate support from healthcare providers since switching to DIY AID?

3. Are your family and friends aware that you are using DIY AID and if so have they been supportive of this?

4. Do you feel that there are any risks with using DIY AID, if so what are they?

Benefits of DIY AID Use

1. What do you feel to be the main benefits to you of DIY AID use?

2. Are you aware of Commercial AID and if so, what do you think are the benefits of DIY AID relative to commercially approved hybrid closed loop systems?

3. Do you engage in any social media platforms relating to DIY AID use? What do you see as the role and the benefits of these platforms?

4. Would you recommend DIY AID to other people with type 1 diabetes and why?

Other

1. Is there anything else that you think is important to discuss about the use of these systems or anything else you would like to mention?

Thank-you for answering these questions and taking part in our research. All answers are anonymized and confidential.

Figure 4.1.2 Interview data coding framework

Coding categories and subcategories

Quality of Life

- Lifestyle flexibility – diet, exercise
- Sleep
- Autonomy
- Psychological burden of diabetes- time spent thinking about diabetes, distress and burnout.

Glucose variability

- TIR and HbA1c
- Hypoglycemia
- Diabetes complications and co-morbidities
- Pregnancy and female health
- Safety features

Technology

- Technology access and sourcing hardware- financial costs
- Knowledgeable in technology 'techy person'
- Technology issues- connection, carrying all components, battery life, set up time

User concerns and perceived risk

- Pre-Loop treatment dissatisfaction
- Fear
- System failure
- Use of old pump
- Incorrect settings
- CGM inaccurate readings

Support mechanisms

- Industry
- Social media and other internet resources
- Family and friends

Local factors

- HCP
- Coverage- Alberta pump program and Sensor coverage

Figure 4.1.3 DIDS questionnaire

1. How satisfied are you with your [insulin delivery device]?

Very Unsatisfied									Very Satisfied
1	2	3	4	5	6	7	8	9	10

2. How much do you trust your [insulin delivery device]?

Not at all									A lot
1	2	3	4	5	6	7	8	9	10

Please indicate how much you agree or disagree with each statement based on your experienceusing your [insulin delivery device].

My [current insulindelivery device] …	Strongly Disagree 1	2	3	4	5	6	7	8	9	Strongly Agree 10
3. …is easy to use.	○	○	○	○	○	○	○	○	○	○
4. …helps me have goodblood glucose control.	○	○	○	○	○	○	○	○	○	○
5. …is a hassle to use.	○	○	○	○	○	○	○	○	○	○
6. …helps me feel more in control of my diabetes.	○	○	○	○	○	○	○	○	○	○
7. …is too complicated.	○	○	○	○	○	○	○	○	○	○

How often do you…?

	Never 1	2	3	4	5	6	7	8	9	Always 10
8. …have a bad night sleep dueto diabetes?	○	○	○	○	○	○	○	○	○	○
9. …wake up at night to treat alow blood glucose?	○	○	○	○	○	○	○	○	○	○
10. …worry about going low?	○	○	○	○	○	○	○	○	○	○
11. …miss work, school, chores, or other responsibilitiesdue to diabetes?	○	○	○	○	○	○	○	○	○	○

Scoring Instructions:

Device Satisfaction: Average of items 1 - 7 (#5, #7 are reverse scored)

Diabetes Impact: Average of items 8 - 11

Figure 4.1.4 INSPIRE questionnaire

INSPIRE Questionnaire for Adults with Type 1 Diabetes
(Post Intervention)

We would like to ask about your thoughts and feelings about your experience using an automated insulin dosing system(**abbreviated AID**), sometimes called a closed loop system, artificial pancreas or bionic pancreas. We would like you to think about living with diabetes and the things that may have been better or worse by using **AID**. **For each of the questions below, please tick (check) the box that best fits your answer. Please answer every question.**

		Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	N/A
1	I was more hopeful about my future when using automated insulin dosing (AID).	□	□	□	□	□	
2	I worried less about diabetes with AID.	□	□	□	□	□	
3	AID reduced my family's concerns about my diabetes.	□	□	□	□	□	
4	AID made it easier for me do the things that I wanted to do without diabetes getting in the way.	□	□	□	□	□	
5	AID decreased how often I had low glucose levels.	□	□	□	□	□	
6	AID decreased how often I had high glucose levels.	□	□	□	□	□	
7	AID helped me stay in my target range more often.	□	□	□	□	□	
8	AID improved my A1c to target level.	□	□	□	□	□	
9	AID made it easier to eat when I wanted to.	□	□	□	□	□	
10	AID made it easier to exercise when I wanted to.	□	□	□	□	□	

		Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	N/A
11	AID made managing diabetes easier when I was at work or school.	□	□	□	□	□	
12	AID made managing diabetes easier when it came to my social life/being with friends.	□	□	□	□	□	
13	AID helped me manage sick days.	□	□	□	□	□	
14	AID helped me sleep better.	□	□	□	□	□	
15	AID helped me have fewer hypos during the night	□	□	□	□	□	
16	AID improved my overall quality of life.	□	□	□	□	□	
17	AID improved my family's overall quality of life.	□	□	□	□	□	

		Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	N/A
18	AID made managing diabetes easier when driving (for those who drive) or when travelling	□	□	□	□	□	
19	AID helped me manage diabetes when it came to my sex life	□	□	□	□	□	
20	AID helped me manage my diabetes when I drank alcohol	□	□	□	□	□	
21	AID helped me when I was pregnant	□	□	□	□	□	

22	AID reduced my risk of long-term complications.	□	□	□	□	□	

Thank you for taking part, your answers are very important to us.