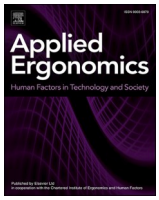
Applied Ergonomics 122 (2025) 104392

Contents lists available at ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo



Contributions of digital technologies for resilience capacity in a type 1 diabetes transition clinic: A qualitative study

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ARTICLE INFO

Keywords:
Resilient healthcare
Diabetes
Technology

ABSTRACT

A type 1 diabetes (T1D) transition clinic in Sydney, Australia, provides age specific care for young adults (aged 16–25 years) and for adults (aged 21 years and above), and has reported improved clinical outcomes post transition to adult care over a 21-year period. This study investigated the contribution of digital technology to long-term resilient capacity of the clinic. Clinic observations and interviews with eight providers and 17 young adults were conducted. Using a framework to analyze resilient capacity in healthcare, seven strong themes emerged from the data: Leadership, Involvement, Communication, Coordination, Risk Awareness, Competence and Alignment with three themes, Structure, Learning and Facilitators also supported. Patient service adaptations included offering out of hours appointment times and telehealth to accommodate young adults' availability. This study provides evidence for the important role that digital technologies contribute to a system of care with capacity for resilience. Our findings contribute to the understanding of the factors needed to support young adults with T1D and may be valuable to inform models of care for young adults living with other chronic health conditions.

1. Introduction

Type 1 diabetes (T1D) is a chronic, incurable condition that occurs when the pancreas fails to produce insulin to safely control blood glucose levels. The onset of T1D typically occurs in childhood and of the 8.4 million individuals living with T1D globally, 18% were aged < 20 years (Miller et al., 2015). It is estimated that children and adolescents with T1D have a reduced life expectancy of 12–16 years compared with non-T1D peers due to co-morbidities such as cardiovascular disease (Harding et al., 2014). Although individuals living with T1D typically understand these risks and the importance of maintaining glycemic control, registries show that less than 20% are able to achieve recommended glycemic targets (Holmes-Walker et al., 2023; Miller et al., 2015; Phelan et al., 2017).

Treatment adherence rates for young adults (YAs) reduce significantly during transition from pediatric to adult care largely due to changed life events around education, new employment, and social demands (Lotstein et al., 2013). This has resulted in greater attention on the need to develop innovative, interdisciplinary models of care for young people transitioning from pediatric to adult care (Zurynski et al., 2023). At the same time, innovative therapies, technologies, and digital technologies (DT) have emerged that are proving beneficial for YAs

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https://doi.org/10.1016/j.apergo.2024.104392
Received 29 January 2024; Received in revised form 8 September 2024; Accepted 17 September 2024
Available online 26 September 2024

living with T1D to manage their diabetes with emerging evidence for improved glycemic control (Wadwa et al., 2023), and quality of life (Sun et al., 2019).

1.1. The development and application of digital tools for type 1 diabetes

Over the last century there have been major advances in the treatment, management, and accessibility of information for people with T1D that has improved clinical outcomes and quality of life, and subsequently reduced the burden of disease management (Aathira and Jain, 2014). Specifically, in the past decade, technological advances have produced, for example, minimally invasive continuous glucose monitors (CGM), that tracks and records glucose levels, the so-called hybrid closed-loop system or "artificial pancreas" that delivers automatic subcutaneous insulin infusion (pump) to dose insulin more effectively, cloud-based storage of continually acquired monitoring data, smartphone T1D management and communication tools, and smartphone mobile applications (apps) easily accessed by individuals and healthcare providers which supports timely treatment and management (Sherr et al., 2022). The International Society for Pediatric and Adolescent Diabetes (ISPAD) guidelines recommend that all youth are offered the most advanced technology available while considering affordability and personal preferences for integrated wearable devices (Sherr et al., 2022). Crucially, DTs have reduced occurrences of diabetic ketoacidosis, a life threatening complication caused by low insulin levels (DKA) (JDRF Australia, 2024). In Australia, data registries have reported that 79% of participants aged $<$ 21 years are using a CGM (Johnson et al., 2022). CGM is a particularly helpful tool for parents who have the capability of viewing their child's glucose level remotely via a mobile phone app and be reassured when insulin is delivered at the appropriate time, such as during school hours, and overnight.

Aside from the clinical advantages, automated systems can also improve quality of life, and reduce the burden associated with diabetes management, especially for YAs (Papadakis et al., 2020). Another major advantage is that clinicians have access to data that is digitally backed up to the cloud so that they can monitor glucose levels remotely. This is particularly important for individuals who may not always be able to attend a clinic in person such as during a pandemic or when they live in a remote location.

The benefits for advanced DT use in a T1D context include how it can be adapted to the person with diabetes and their carers preferences, support communication and how it potentially increases both abilities to monitor and respond to changing health needs. However, a considered approach to the introduction of these devices is needed and expectations as well as the potential risks and barriers should be discussed between providers and individuals. Barriers include increased demands on self-management of T1D, emotional challenges, alarm fatigue, physical discomfort from wearable devices, physical limitations (e.g., swimming) and technical errors (Sherr et al., 2022). Additionally, there are risks related to the security, integrity and confidentiality of data that is continually collected, stored on networks and on cloud servers and accessible via mobile devices. However, strict storage, access protocols and data encryption provide protection (Mehrtak et al., 2021). Although devices are a good fit and beneficial for most young people and their families, utilization of these tools is complex and dependent on many factors. Therefore, providers must avoid assumptions about personal preferences and be open to patient-led adaptations to maintain quality healthcare and patient wellbeing.

1.2. Resilience in healthcare

One way to understand the provision of safe and high quality healthcare is to examine healthcare through a Resilience in Healthcare (RiH) lens (Aase et al., 2020). Wiig and colleagues established a RiH research program in 2020, and define RiH as "the capacity to adapt to challenges and changes at different system levels, to maintain high-quality care" (Wiig et al., 2020, p.8) in a complex adaptive system comprising a variety of stakeholders and processes that are interconnected, often working in unpredictable and interdependent ways (Braithwaite et al., 2017, 2021; Plsek and Greenhalgh, 2001). During times of uncertainty and change in a dynamic environment, stakeholders at the micro-level engage adaptive capacities such as work-arounds to anticipate, respond and maintain quality and safety prior to, during or following events (Hollnagel et al., 2015; Wiig et al., 2020). Resilience as a perspective for understanding patient safety provides a shift through the focus on not just learning from errors and adverse events, as in the traditional patient safety perspective, but instead include learning from what goes well in the organization. As such, using a resilience perspective is a useful route for developing understanding of how some organizations can succeed in providing a better quality of care despite operating under the same level of pressure (Haraldseid-Driftland et al., 2022; Hollnagel et al., 2015; Lyng et al., 2022).

1.3. Resilient capacity and digital technology

Digital technology plays an important part in supporting resilient capacity to support function by providing timely evidence through monitoring, to enable systems to anticipate, respond, adapt, recover and learn (Carrigan et al., 2023b; da Rosa et al., 2021; Saurin et al., 2024). Resilient capacity is dependent on the availability and effective use of resources utilized to manage a disturbance or change which drives resilient performance, the outcome of how well resilience capacity is applied in practice (Braithwaite et al., 2015). During the COVID-19 pandemic, adaptations such as remote consultations via telemedicine reduced cross-infection in emergency departments and supported knowledge sharing (Tonetto et al., 2023). There is also evidence for shared situational awareness when nurses remotely monitor healthcare assistants who are working with patients in their homes (Karnehed et al., 2022). Situational awareness is critical for providers working with individuals living with T1D as sudden changes in blood glucose levels can lead to life threatening events such as DKA. As YAs transition from pediatric to adult care, they may build capacity to work with staff, be involved in their own care and learn how to safely use DTs to monitor glucose levels and anticipate fluctuations and adverse events prior to these occurring, ensuring care quality and safety. Therefore, examining the underlying mechanisms involved in these resilient capacities supported by DTs is a key component of a safe system of care.

In response to calls in the literature to further operationalize RiH (Berg et al., 2018; Ellis et al., 2019), Lyng et al. (2022) developed a conceptual framework that builds upon the four mechanisms proposed by Hollnagel (2017): anticipating, responding, monitoring and learning. The framework identifies key capacities for resilient performance based on a synthesis of evidence from empirical research studies conducted in a range of contexts and consideration of internal and external influences (Lyng et al., 2022). Using a grounded theory approach, ten capacities for RiH emerged from the data: Structure, Learning, Alignment, Coordination, Leadership, Risk Awareness, Involvement, Competence, Facilitators and Communication. This framework provides a guiding structure to explore how DTs contribute to RiH in real-world settings. The contribution of DTs to RiH in a T1D outpatient setting has not been previously explored.

1.4. The case of a T1D transition clinic that has sustained health outcomes for young adults post transition to adult care

The transition from pediatric to adult services is a significant milestone for YAs as they take on full responsibility for their day-to-day T1D management and parents and supportive pediatric services take a step back. Therefore, it is a challenging time that often results in suboptimal outcomes. It has been suggested that a contributing factor to deterioration in glycemic levels during adolescence stems from a lack of implementation of comprehensive and sustainable transitional models of care

(Zurynski et al., 2023). In Western Sydney, Australia, a YA T1D transition service located in a tertiary adult referral hospital, has consistently reported improved diabetes control and reduced unplanned hospital admission rates up to 30 months post transition among YAs aged 16–25 years (Farrell et al., 2018; Holmes-Walker et al., 2007). Importantly, these outcomes have been sustained for over 21 years and hospital admissions are below the national average (Holmes-Walker et al., 2023). Holmes--Walker et al. (2007) reported that there are high rates of adherence to clinic attendance, and significant reductions in high levels of HbA1c (blood glucose), DKA, admissions and readmission length of stay, post transition, across a five year period (Holmes-Walker et al., 2007). The YAs transition mostly from the tertiary pediatric hospital located adjacent to the young adult clinic where around 250 YAs per year receive care from a multidisciplinary team (MDT) comprising an endocrinologist, a transition coordinator and a diabetes educator. The clinic team involves dieticians if a need is identified. Additional professionals may be seen during the clinic visit or referred for mental health or social supports. One of the key contributions to these findings were < 6 months interval to first scheduled appointment, reduced loss to follow up by enabling continuity of care (from transfer from the pediatric service) or by re-establishment of connections with the YA clinic.

Data from our recent review showed that non-attendance at a clinic is a frequent issue for YAs (Zurynski et al., 2023). Here, the clinic has adapted by offering mobile phone text messaging and/or email appointment reminders, pro-active rebooking of missed appointments, after hours support for sick day management, and evening appointments (Holmes-Walker et al., 2007). It has been suggested that the model's success is attributed to appropriate support for YAs from a skilled and experienced MDT providing care that is T1D specific, age-appropriate and flexible to fit with young people's needs, preferences, and capacities thus increasing adherence to self-management regimes (Farrell et al., 2018).

Given the known reduced clinic adherence rates and subsequent negative outcomes for YAs (Lotstein et al., 2013), and that modern work processes in healthcare are becoming digitised and automated, and integrated within a social system (Carrigan et al., 2023b; Patriarca et al., 2021), it is crucial that we understand the role of DTs in resilient capacity to build knowledge of the underlying mechanisms or capacities that contribute to the clinic's long-term, positive outcomes.

1.5. Aims

This study aimed to examine the contribution of DTs for resilient capacity in an established young adult T1D transition clinic, specifically with regards to anticipation, adaptation, response, recovery and knowledge. Based on the foregoing, our research question was: How do DTs for T1D contribute to the capacity for resilient performance in the T1D transition clinic to ensure continuity and favourable clinical outcomes?

2. Methods

2.1. Study design and setting

We conducted a detailed, multi-method case analysis of a T1D transition clinic and adjacent pediatric outpatient clinic, examining the role of DTs in resilient capacity on the micro and meso levels. We adopted a co-design approach involving healthcare providers, researchers, and a YA living with T1D who were consulted at all stages of the study via regular meetings and communication. This process ensured that the research design was meaningful and relevant for the end-users (Slattery et al., 2020). During the period of observations, the T1D clinic had recently moved to a specifically designed space - the multidisciplinary Young Adult Clinic developed for young people living with any chronic condition. The space was being used by the YA T1D clinic for several sessions a week.

We undertook four methods of data collection:

1. Ethnographic observations in clinics at two sites in Western Sydney, Australia: 1) Westmead Hospital, an adult hospital where the transition clinic is located and, 2) the Children's Hospital at Westmead, to explore transition preparedness within a pediatric diabetes clinic.
2. Qualitative interviews with health care providers and teams who provide care to young adults living with T1D, at both sites.
3. Qualitative interviews with young people ages 16–25 years, living with T1D who attended the YA clinic at Westmead Hospital.
4. Qualitative interviews with children (<16 years) living with T1D and their families who were being prepared for transition at the Children's Hospital at Westmead.

Ethical approval for the study was granted by The Sydney Children's Hospitals Network Research Ethics Committee (2023/ETH00404) and Governance approval was granted by Westmead Hospital (2023/PID00455, STE00965) and The Children's Hospital at Westmead (STE00964).

2.2. Participants and sample characteristics

Healthcare workers, YAs and their families were recruited through the transition program contacts, social media and email adverts, through snowballing, and approaching potential participants in the clinics. Seven health care providers (two from the Children's hospital, five from the YA clinic) consented to be observed. Eight providers (five from the Children's hospital, three from the YA clinic) participated in the interviews. Two were endocrinologists, three diabetes educators, two clinical nurse consultants and one clinical support officer (Table 1).

Twelve YAs consented to be observed and 17 YAs, including one from the Children's Hospital, one attending the clinic for the 1st appointment, and one parent of a YA with special needs, participated in an interview. Ages of the YAs ranged from 16 to 25 years: ≤ 18 years (n = 5), 19–20 years (n = 3), and 21–25 years (n = 10), with age of T1D diagnosis ranging from 6 months to 20 years. Fourteen participants lived

Table 1
Provider role and characteristics for eight providers who participated in an interview.

Role	Description	Location
Clinical nurse consultant	Coordinator of the service – the workload, the education, and the clinical work for the nursing staff. Also, the case manager for all the young people who are referred to the clinic	Young adult clinic
Endocrinologist	Clinical lead for staff who provide services to young adults	Young adult clinic
Diabetes educator	A clinical nurse specialist working with the clinical nurse coordinator to assist running the clinic	Young adult clinic
Pediatric endocrinologist	The medical lead of diabetes services and co-head of department who manages the diabetes team and the wider group of pediatric endocrinologists. Also looks after a cohort of their own T1D individuals from early childhood right up until the age of 18 and manage their transition when required	Children's Hospital
Clinical support officer	Ensures all clinicians have their rooms ready, the educators and the whole team is organized. Also, prepares the resources for the individuals with T1D (e.g., transition and motor vehicle driving)	Children's Hospital
Diabetes educator	A clinical nurse specialist in diabetes education and management	Children's Hospital
Diabetes educator	Nurse manager of the diabetes service	Children's Hospital
Clinical nurse consultant	Clinical nurse consultant for diabetes	Children's Hospital

in Northwestern Sydney, one in Southern Sydney and one in the inner city of Sydney. One YA attended the clinic from the Central Coast region, NSW (~80 km distance).

2.3. Data collection and analysis

The observations were performed by three researchers (AC, PNAD, ShW) who shadowed healthcare workers at both sites during clinic visits. Researchers attended the YA clinic for 5 x 5-h shifts and the Children's Hospital clinic for 3 x 4-h shifts. Central concepts drawn from the resilience literature such as evidence for adaptive capacities were applied for the observations and interviews. Information about the types of DTs used and whether there were any associated challenges were also explored. Fieldnotes were recorded during the clinic enabling a detailed examination of the clinic's workflow and processes. Only information on generalizable workflow and participant perspectives were collected, not individual medical information.

The interview guides were pilot tested with two T1D clinicians, researchers and a YA living with T1D. Trained qualitative researchers (AC, PNAD, ShW) collected the interview data from consenting providers and individuals from each site until data saturation was reached. Questions explored what was working and not working well in the clinic, what DTs were used and their associated strengths and barriers, whether there have been any issues using technology and who provided support. Interviews were audio recorded and transcribed verbatim via MS Teams and lasted ~20–40 min.

Fieldnotes were deidentified at the time of recording and aggregated for analysis using NVivo V.20 software for data management and analysis. All audio recordings were deidentified, transcribed and once checked by the research team against the audio recording were imported into NVivo. The transcripts were first analyzed inductively by five authors and qualitative experts (AC, NS, ShW, PNAD, HBL) to identify data driven patterns using an open coding process (Braun and Clarke, 2012), and then deductively using a theoretical resilient framework that described ten resilient capacities (Lyng et al., 2022) (Table 2). The outcomes of these processes were synthesized for the final analysis to identify any unique findings and examine alignment with the framework. Four senior authors and qualitative experts in the RiH literature worked with the team to verify the findings (SW, HBL, JL, LAE). Provider and young adult data were merged for the analysis and the data were synthesized to describe the contributions of DTs for the provision of T1D care, and where the data aligned with the ten capacities of RiH. The team worked together to ensure the process was rigorous, discussed major and minor themes and their concomitant categories, and arrived at consensus opinion if any variance in agreement occurs.

Table 2
Deductive analytic framework applied to the observations and interviews based on the ten capacities for resilience in healthcare in the context of digital technologies (Lyng et al., 2022).

Capacity	Description
Communication	Devices, electronic, teams
Structure	Technology, equipment
Learning	Knowledge acquisition, training
Alignment	Adaptations and trade-offs based on requirements, self-organization within a team and own work
Coordination	Team cohesion, multidisciplinary teamwork, inter-organizational coordination, buffers, continuity
Leadership	Supportive and empowering, transparent and open communication, visibility at the frontline of care, decisive
Risk awareness	Emergency preparedness, proactive responses
Involvement	Patient, family, other stakeholders
Competence	Experience, knowledge, understanding
Facilitators	Information brokers, champions

3. Results

To address our research question, we analyzed the results at the micro level, patients and teams, and meso levels, the clinic and inter-clinic relationships and referral pathways. Within both clinics there was evidence for use of CGM, insulin pumps, data storage and management, SMS messaging and mobile apps (Table 3). When provided at no cost (for those 21 years and under, or covered under a private health insurance scheme), most of the participants reported being fitted with a CGM upon initial diagnosis or shortly after in the pediatric clinic in conjunction with an insulin pump and its supporting integrated software. Although some challenges such as burden and stigma were associated with DTs (e.g., wearing visible devices such as a CGM), almost all the YAs endorsed the benefits of using devices to safely manage their T1D. These included the automaticity of digital information transmission, rapid information transfer and ease of use. The YA's weight, height and HbA1c, measured using a desktop point-of-care analyzer at both centres, were recorded by a diabetes nurse and two weeks of recent CGM data were downloaded from the individual's device for the endocrinologist to assess during the consultation.

The data that emerged from observations and interviews with providers and YAs align strongly with seven of the ten RiH capacities described by Lyng et al. (2022): the pivotal importance of Leadership, Involvement, Communication, Coordination, Risk Awareness,

Table 3
Digital technologies observed in the study, their purpose and implications for resilience capacity.

Digital technology	Purpose	Implications for resilient capacity
SMS messaging	Communication between providers and YAs about appointment schedules, blood glucose data and clinical concerns	Adaptations to facilitate clinic attendance, anticipation and communication about changes to blood glucose levels and support
Mobile apps	T1D resources and communication	Resources supporting YA anticipation of adverse events and learning. Receives information from CGM. Facilitate autonomy in glycemic management
Cloud-based data storage and management	Stores CGM data for providers to assess	Acquisition and storage of clinical data that is easily uploaded by YAs and accessed by providers in the clinic and remotely outside of clinic attendance to facilitate emergency care advice
Continuous glucose monitor	Tracks and records blood glucose levels in real-time	Monitors blood glucose levels and sends readings to a separate device for action by the user. Provides alerts for high and low blood glucose to prompt timely action to prevent glycemic emergencies
Insulin pump	Delivers basal insulin as programmed and bolus doses are user initiated. If linked to continuous glucose monitor capacity to suspend insulin delivery to prevent hypoglycemia	Dependent on user initiated bolus dosing for optimal outcomes. Reliably deliver basal insulin if user regularly changes cannula for insulin delivery
Hybrid closed-loop insulin pump	Combination of a CGM, algorithm and insulin pump. Facilitate automated insulin delivery and improves glycemia in the absence of user bolus dosing for meals	Responds to changes in blood glucose levels and adapts insulin dose improving glycemic outcomes including in the absence of user interaction

Note. T1D = type 1 diabetes; CGM = continuous glucose monitor; YA = young adult.

Competence, and Alignment. There was also evidence to support Structure, Learning and Facilitators with instances of overlap among the capacities (e.g., Coordination and Facilitators). These are summarized in Fig. 1 and described in detail below. Our results also support Hollnagel's (2017) potentials for resilience: *monitoring* of glycemic levels via CGM data, retrospective and in real time, *anticipation* of trends in CGM and insulin pump data, *responses* to perturbations are timely and targeted, and the system at a micro level continues to *learn* and adapt to YA's preferences and needs with respect to technology. Relevant participant quotations are reported in Table 4 through to 12. For quotes, the following codes were applied: PW# = young adult clinic provider, PC# = pediatric hospital provider, YA# = young adult who attended the young adult clinic, YAC# = young adult who attended the pediatric hospital.

Table 4
Provider quotations for Leadership.

Quote number	Quotation
1	We don't have official ones (MDT meetings), like we don't have an afternoon where we meet to discuss different patients. We will discuss it usually at clinic or after we finish the clinic. PW1
2	We might have a couple of formal meetings, particularly with, we've got research projects planned, and maybe when there's new team members joining, so when we get a new dietitian, join the service, which just happened a few times … anytime we get new registrars at the start of the year, I will have a meeting with each of the new registrars about the clinical approach that we take. PW2
3	Once we are busy, we cover each other well. PW1
4	I have multiple different registrars who come through the clinic over time and I tried to keep the continuity factor that I see pretty much most people every time they come, even if it's short. PW2

3.1. Resilience capacities in long term diabetic care

3.1.1. Structure

The pediatric and adult hospitals were co-located in the same precinct facilitating a smooth transition between T1D services. The clinics were located within an outpatient setting with similar layout and structure. The YAs reported that their transition, in terms of structure, was a straightforward process enabled by digital communication. The introduction and maintenance of DTs was also structured, adhering to recommended ISPAD guidelines (Sherr et al., 2022).

3.1.2. Leadership

Leadership of the senior endocrinologist and the coordinator are paramount to the success of this model of care who lead a team of dedicated, skilled, and knowledgeable professionals. The leadership team mostly utilize informal arenas to communicate with other registrars or staff (Table 4). This involved discussing patients between consults, at handover, or at the end of the day, which created an open forum for coordination between the leaders and other staff (Quotation 1). Leaders adhered to the ISPAD guidelines, ensuring that all YAs had access to and understood DTs. The leadership style was collaborative, supportive and empowering for junior staff and YAs. Leaders in this clinic also provided training support and learning opportunities for registrars and other staff members, sometimes through formal meetings. This would often take an individual approach, where the endocrinologist would meet with new registrars and discuss the clinical model of the clinic (Quotation 2).

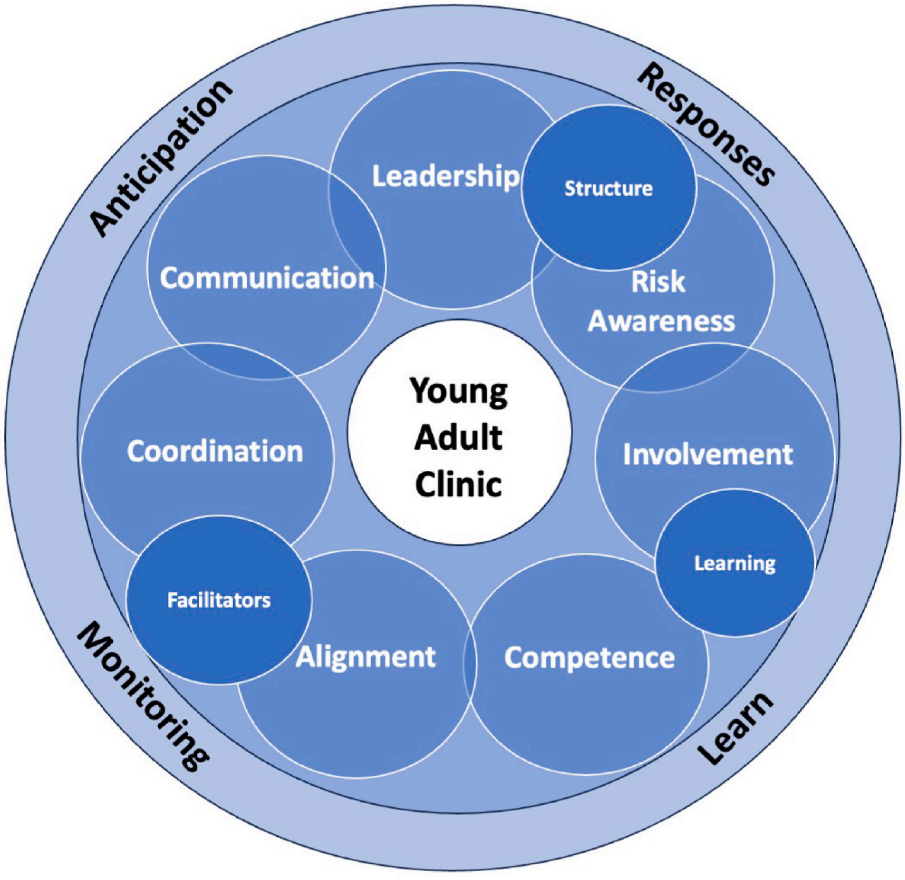

Fig. 1. The ten capacities of Resilience in Healthcare (Lyng et al., 2022) supported by the four potentials (Hollnagel, 2017) that emerged from the observations and interviews at the Children's Hospital and Young Adult Clinic.

Table 5
Young adult quotations for Involvement.

Quote number	Quotation
1	Well for example, like the CGM, they give you all the information and it's ultimately your decision … Yeah, it's patient centred. Definitely yeah, very patient centred. I f you say no, they're like, "Ok fair enough". But they make sure you have your own, kind of, responsibility for your own health, because otherwise they know it's not going to work. YA9
2	They (staff) provide you with information but really they're putting the onus on you. YA1
3	Mum was there to help, but I just mainly thought, just gotta do it. It's all for my health anyway. YA10

Table 6
Provider and young adult quotations for Communication enhanced by technology.

Quote number	Quotation
1	So just being able to send a message at any time to organise appointments, to ask, to check my blood sugar levels or graphs for adjustments to carb sensitivity or basal rates or anything like that, just actively quick, convenient and I think everyone here is quite helpful with it. Also, if there's any technological problems if I can pull up and just response … it's just a brief conversation like. Yeah, that's a common issue. Here's how you circumvent it. Yeah, or sometimes even just texting. So I mean, even as … as an example, just getting simple text is being like the transition clinics moved. You know that … that's helpful. YA14
2	The app that I mentioned or even the (CGM) clarity stuff, they're better. They're really good at the retroactive analysis. So going in and seeing, hey, I made a change last Sunday, how have the last five days since then been, can I see that this, you know, my averages are slightly down or that I'm in range for a longer period of time. YA13
3	It's very flexible. It's good cause they know everyone in this age group is doing very different things with life and working or studying or … yeah, no one's working a nine to five job in this age group, so I find that very good. I love that there's after hours support. I frequently have to ring in or text message when things are going wrong at home. And I love that there's always someone to answer instead of having to come into a hospital when you have issues. So that's the main thing. Just it just feels really is casual and friendly. Like, it's not … Yeah. It's like a check in as well as an appointment. And there's no judgement. YA3
4	"Oh, maybe we'll do this", but sometimes I do it, you know, I talk to them myself when I when I have them initially, and I'll say, you know, "Do you think you'd like to try that again?" And if they show some interest, I'll do it straight away, because that way I'll say, "Oh, it'll be in, it'll be up and running by the time you leave, and you'll be able to see what's happening". And yeah, so you know, becomes a positive thing and you need to act on it. You just don't say, "Oh, we'll think about that or maybe we'll get you back". It's very reactive if they're happy to do it. PW1
5	And it was kind of … presented to me as this is an option, but you don't have to go down this route. But this is why we think it would work for you. And then I had 1000 questions and wanted to take time and think about it and they sent me resources and they answered all my questions, no matter how silly they sounded. There was that strong sense of, as my medical team, they were advising me on what they think I should do, but that ultimately, whatever I wanted to choose was my choice and they'd support me and keep me healthy through that, which has been pretty awesome. YA3
6	We could still have meaningful discussions about caring for themselves during COVID when they were isolated and to make sure that they knew where to reach out to if they became unwell and who to contact and when to contact. So, that was all about quality and safety. PW2
7	I think COVID was good because we taught a lot of people how to upload that information to computers so that they could send and share that information. I think it gives individuals a bit more autonomy in caring for themselves. PW2
8	I created a different approach to get the data. I refer them (parents) to speak to an educator to improve their process in involving the YA in making them responsible. PC2

Table 7
Provider and young adult quotations for Coordination.

Quote number	Quotation
1	During pregnancy, they're looking at (insulin data) every two weeks to every week and prior to that, it was every three months. YA7
2	There was a lot of talking about what was going to be different, preparing before we actually moved here (YA clinic). And then I remember the first few appointments coming in and I don't know what handover went on in the background, but it's like they already knew me before they met me. They knew my full history. They knew what was going on. So, it was very, very smooth transition from both ends okay. YA3
3	People know that they will be contacted (by the clinic coordinator). PW2

Table 8
Provider and young adult quotations for Facilitators.

Quote number	Quotation
1	We like to contact them first by phone. So, it's quite a welcoming type of contact to start. Then we text. PW1
2	There's a culture that we have tried to foster, that's, you always make someone feel welcome for coming and that you're pleased to see them whenever they come, whether it's been two years since they've been, three years since they've been, or they came one week ago. PW2
3	In this climate, I think it's incredible. I come in, I feel like they know me as a person as well as just a patient, which is positive. There's no anxiety when I'm walking in. No matter how bad things are on paper, it's always friendly faces. YA3

Table 9
Provider and young adult quotations for Risk Awareness.

Quote number	Quotation
1	I also think in the clinic the big focus is always on reducing hypos because obviously the hypo is far more dangerous than the high in a lot of situations and so sometimes, to a point that I like, sometimes it's taken a little bit too far, but it's probably better in the interest of safety, is trying to cut out pretty much all hypos from the day is one of the goals that I think is there when they're making me the adjustments. YA13
2	They are proactive in suggesting some things. Like at my last meeting for example, I mentioned 'cause I needed a travel letter, I mentioned that I was going away and they sort of, the person I was seeing sort of jumped into a "Do you have this? Do you have this? Do you have that?" and that was, I mean, I go away regularly and I'd completely forgotten for example to pack long-acting insulin 'cause I'm on an insulin pump normally and so I would almost always only ever take short-acting and it just … it had slipped my mind to order that. YA13
3	I think that's a really useful tool. I think the reassurance for safety for hypoglycemia for instance, for continuous glucose monitoring, in those who maybe have a fear of hypoglycemia. PW2
4	I train my staff not to place too much burden of tasks on the person and kind of coming to mutual decisions about what would be one thing person could do that might make a difference for when they came back and not having a whole list of things to do. PW2

One of the main drivers of the leadership in the clinic is the clear emphasis on continuity and coordination between providers with no apparent hierarchy. Several providers and YAs noted that being able to see consistent staff contributed to the positive culture, and that if needed, providers could cover each other's roles and share the workload to improve efficiency (Quotations 3 and 4).

3.1.3. Involvement

There was evidence that involvement from a various of stakeholders were presented in clinics with a strong sense of compassion and

Table 10
Provider and young adult quotations for Competence.

Quote number	Quotation
1	Obviously, on the days of clinic, you know we do HbA1c, we do BP (blood pressure), and get pump downloading, and whatever the devices get ready, documentation, if something's needed, we do that too. If they want some device done on a day or an education element like hypos or whatever, we do that on the day. PW3
2	Well, the decision making usually comes from the analysis they give you. They sit down, give you one-on-one and like what … you should like work on, how you should improve on, like problems that you're having regularly. They'll see the pattern when you upload your data. YA4
3	But then there's also been times where I've gone … I'm crumbling. I don't know what to do. I need someone else to take over and they've swooped in and made decisions for me with my consent, and that's been really helpful as well. YA3
4	Oh yeah, they always do it (make adjustments to the pump) in front of you which is really good. And I sometimes forget how to change the things in my phone. The doctor is really good at showing me how they're changing it as well. So not only … I'm saying what's going on, I'm also being taught what's going on. YA11
5	They're so, like, know what they're talking about. So if I'm doing something wrong, they will say "if you do this one thing, it will fix what's going on". They said I can do it. I'm ready and willing to listen. And they also listen when I have concerns or if I'm confused. YA11
6	But I think being able to come here and have all of my graphs looked at as well and that's something I keep bringing up, but it's really true because I don't know how to actively do the math for my own insulin sensitivity, carb ratios and that side … that's really helpful. YA14

Table 11
Provider and young adult quotations for Alignment.

Quote number	Quotation
1	They really make sure that I was looking after myself. Even if, you know, there was weeks where I was like, I don't really wanna go because this week I've kinda fallen off the wagon and I didn't really take care of my sugar levels, they would be like, "Okay, but we're doing it on telehealth, if you're not coming in, we're gonna do it on telehealth." YA7
2	We adapted new technologies, we got patients to adapt to, using new technologies, learned to upload devices where they'd previously been dependent on staff to upload devices. They learned how to do it themselves. They did that well. We could still have meaningful discussions about caring for themselves during COVID when they were isolated and to make sure that they knew where to reach out to if they became unwell and who to contact and when to contact. So, that was all about quality and safety. PW2
3	We did the telehealth stuff a little bit. I actually loved that because the way that it ran was you uploaded all of your data a day or two ahead of time and then you would get a phone call from someone on the day of your appointment, and they'd already reviewed your data. And so, I think I had one appointment that was like 15 min on the phone and that was it. There was no waiting, no getting the train there, no driving there. YA1
4	The other thing that I tend to do is if I notice a bit of a pattern in my blood sugar, I will make an adjustment myself before going to the clinic. It's just kind of something to do on an ongoing basis. They don't always seem to like that, but generally after, I can explain it to them or say that you know, "I saw a low at this time everyday" or whatever, and they'll understand it. YA13

understanding, like a "second family" (YA13) with care provided in a non-judgemental way (Table 5). The healthcare personnel tend to adopt a patient centred decision approach, which give patients a sense of autonomy and empowerment. During the decision-making process, the healthcare personnel would provide useful and necessary information to YA for their consideration but ensured that the YA understood that the management of their diabetes was their own responsibility (Quotations 1 and 2).

Table 12
Provider and young adult quotations for Learning.

Quote number	Quotation
1	My role as the clinician is teaching them to be able to use it themselves in a meaningful way to inform what they do without needing me to tell them what to do. They could work that out themselves and watching them, many embrace that and do that themselves and feeling confident to make change themselves rather than relying on me to guide them to make change. PW2
2	I guess a part of the ability to do that (manage digital technologies) has come from seeing what they do when making decisions and they'll generally look for patterns in the data. YA13

The providers often emphasized the importance of independent care for diabetes to YA during the transition, however, the level of involvement was judged based on the patient's age, parental involvement and adjusted as needed. Some YA also expressed that although their carer is supportive and involved in their care, they understood that self-care was important (Quotation 3).

The role of communication appeared to be critical in involvement for care in the clinics. The YAs and healthcare personnel mentioned the need for working together in diabetes care. There was evidence for patient involvement in discussions about obtaining a driver's license, diet, CGM data and adjustments to insulin pumps. If there were any technological problem raised, or there is an intention to change a new device, YA tended to initiate the conversation and the provider referred to the patient for their opinion.

3.1.4. Communication

There was evidence for high use of DT for communication, mobile apps, and social media. Relevant provider and YA quotations are reported in Table 6. YAs were sent appointment reminders via SMS. Compared to other outpatient clinics, one of the key adaptations that the clinic has made was that the clinic was open after hours (until 8pm), increasing the accessibility for YAs who attended work or university. Additionally, YAs had access to a mobile phone number where they could text a provider and receive an answer within 24-h. Knowing there was consistent and reliable means of communication that was offered after regular working hours was convenient and reassuring for the YAs, especially in the context of having more responsibility for their T1D. The YAs appreciated the functionality of apps and CGMs so that providers could have access to and discuss their glycemic patterns. This was especially relevant when the YA made any changes to their treatment that were then verified by the provider.

Communication about clinical concerns, for example, when worried about their devices, or average glucose levels and estimated A1c recorded from the CGM, were also facilitated by DTs. The YA could upload data at any time which would be reviewed within minutes in regular working hours or within 24-h if out of hours by the coordinator and endocrinologist for feedback and advice to the YA via a phone or SMS (Quotation 1 and 2). Providers understood that YAs have busy schedules and offered a degree of flexibility around appointment times (Quotation 3). Providers were supportive but also encouraged autonomy with regards to the YA's T1D care. Providers communicated assertively when a YA was trialling a CGM and focused on the benefits of knowing their glucose levels in real time (Quotation 4).

YAs' needs and preferences were considered when new devices were introduced to a YA or when glycemic patterns were sub-optimal between clinic visits and required monitoring. For example, when providers discussed a possible change from insulin injections to a pump and how this device would reduce the burden of T1D, the YA was provided information that enabled them to make an informed decision, given the time and space to ask questions, and debate the pros and cons (Quotation 5). Additionally, providers built on a YA's existing knowledge of technological devices and listened to their feedback when making

changes to devices. Even when the YA seemed confused, the provider allowed them to work through the problem themselves. Providers suggested compatible DTs and discussed in the context of risk and safety with the YA, prior to any changes to insulin pump adjustments such as dose or frequency. This approach encouraged capacity building for the YA to manage their care via the acquisition of knowledge.

There was evidence of clear communication and learning via adaptations made regarding DTs and data sharing during the COVID-19 pandemic. COVID-19 facilitated the transition to online appointment modes ensuring that DTs continued to be introduced, and that their quality and safety was maintained (Quotation 6). Specifically, providers and YAs commented on the benefits of the rapid upskilling required by YAs to learn how to transmit digital information from their CGMs to the provider so that providers could view and assess the data remotely (Quotation 7).

One provider noted that some communication barriers occur if text messages about CGM data uploads are sent to parents on behalf of the YA, who will then delegate this to the YA. In the instance of the data not being uploaded by a YA, there was evidence for a workaround where the provider identified the need for more parental support to improve this process (Quotation 8).

3.1.5. Coordination

The capacity of coordination within the clinic was supported with evidence for clear processes, leaders and teams that emerged from the data. Relevant provider and YA quotations are reported in Table 7. For YAs being prepared for transition, the pediatric hospital sent a referral letter via email to the YA clinic and the YA clinic transition coordinator contacted the YA via telephone and SMS text to arrange their first appointment. Patient flow processes through the pediatric and YA clinics were similar, apart from the presence of a transition coordinator in the YA clinic, who strove to establish and maintain relationships with the YAs. A consistent transition coordinator who acted as a point of contact, ensured seamless patient flow throughout the visit. The clinic coordinator overcame potential challenges with YA engagement by sending text reminders to YAs about their upcoming appointments, and actively rescheduling them if they failed to attend ensuring care continuity and a person-centred approach.

Organizational risks and challenges such as reduced resources, and links with the pediatric clinic were managed by the team leaders. Having a consistent coordinator who has worked in the clinic for over 21 years was identified as a risk as when they leave there will be a large network and knowledge gaps to fill. However, our interviews provided evidence for succession plans with staff trained into the care coordinator and leadership roles. Staff were reactive in the event of a YA not able to get an initial appointment with the YA clinic for a few months. In this scenario, the YA remained in the care of the pediatric team at the Children's hospital, who liaised with the YA T1D clinic until an appointment became available.

The clinic coordinator was highly visible and well known to patients, which promoted familiarity and warmth within the clinic. YAs also reported that seeing the same team including senior endocrinologists, diabetes educators and dieticians during the transition to adult care was very helpful and supportive, helping to build trust with the YA clinic team. YAs discussed their downloaded insulin data with their healthcare team at the YA T1D clinic, and the frequency of discussions was adjusted according to individual need. For example, pregnant YAs with T1D required tailored care (Quotation 1).

Most of the YAs reported high levels of satisfaction with the care coordination which supported a smooth transition from pediatric to adult care. The transfer of information via email between pediatric and adult clinics was seamless and the patient did not have to explain their medical history repeatedly to the new team members (Quotation 2). Providers also reported on the benefits of having a consistent, full time service coordinator who facilitated appointments and was the main line of contact with the YAs. This ensured that the messaging to the YA was consistent across the team (Quotation 3).

3.1.6. Facilitators

The data that emerged to support the capacity for facilitators was closely related to coordination (Table 8). The transition coordinator is the linchpin in the YA who works with the senior endocrinologist to ensure that once the YAs are referred to the clinic, they are triaged appropriately, and an appointment arranged (Quotation 1). Providers prioritized making the transition process seamless to ensure that YAs quickly settle into the clinic. They fostered a positive and safe culture with a consistent message delivered to the YAs even when the YAs are not attending regularly (Quotation 2). The transition coordinator also has a significant role in coordinating provider roles and informing other staff at the start of the clinic what the general plan for the day is. In addition, they are willing to take on additional tasks, such as maintain a quick response to YA text messages (including after work hours) and involvement in continuous quality audits.

Positive attitudes (e.g., friendly and approachable) ensure that YAs do not hesitate to contact the transition coordinator whenever they need help or clarification, especially with respect to DT which contributes to increased communication between the YAs and healthcare personnel to improve clinical outcomes (Quotation 3).

3.1.7. Risk Awareness

Care in the transition clinic was both proactive and reactive with evidence for emergency preparedness. Relevant provider and YA quotations are reported in Table 9. YAs were involved in their care decisions and made aware of the risks, long and short term, for not attending to maintenance of glycemic levels. Discussions were directly linked to reports from DTs such as the CGM device, which allowed providers to track the YA's data and identify any potential areas of concern that occurred since their last clinic visit. One YA noted that there is generally an emphasis on minimizing hypoglycemia (low blood sugar), which indicates that the providers were aware and proactive in their perception of high-risk safety events (Quotation 1).

Adjustments made to CGMs or insulin pumps were performed in collaboration with the YA to accommodate competing goals. These included trade-offs between YA lifestyle, preferences, and clinical needs. This always involved a discussion about previous glycemic trends by viewing the downloaded CGM data on a monitor together. For example, where the retrospective analysis of CGM data reflected an isolated event in the YAs life such as a holiday causing high glycemic levels, they may not require any insulin pump adjustments. Providers also involved the YA in decisions about adjustments to their insulin pump, which provided a learning opportunity for the YA, but also minimised the risk of error through the process of double-checking. In one instance, we observed a provider error entering numbers that the YA noticed and corrected. The providers also proactively highlighted any potential safety concerns for patients where appropriate. For instance, when patients request travel letters or materials for sick day management (e.g., the YA is sick with the flu which increases insulin doses), the providers in the clinic might bring any other risks to the person with diabetes attention to ensure that all aspects of care are covered (Quotation 2). This proactivity was also evident in their approach to the use of DTs, where it was emphasized that DTs are offered to YAs as a way of ensuring safety and monitoring beyond clinic visits (Quotation 3).

Staff were aware of the risk of burden on a YA that may occur if there is too much emphasis placed on adapting to changes to their care regimen. Workarounds were evident where providers focused on the most important change that was needed, with the understanding that further adjustments would be offered during future visits (Quotation 4).

3.1.8. Competence

Providers were highly experienced and skilled members of a MDT, each with specific roles and responsibilities, who appreciated the complexities of T1D. Relevant provider and YA quotations are reported in Table 10. This cohesive team approach fostered trust, understanding and confidence. There was evidence that a structured approach with DTs enhanced their competence by allowing access to comprehensive data and devices that the YA could use, for example, insulin administration, blood glucose monitoring and lifestyle adjustments. Providers clearly understood their tasks and what actions were required during clinic times (Quotation 1).

Providers could individualize care tailoring treatment plans to suit each young adult's unique needs, considering lifestyle, preferences, and medical history. Their competence was also reflected in their effective communication, empowering patients with the skills and to manage their T1D effectively. Providers were understanding and able to troubleshoot when issues arose with devices. This was endorsed by the YAs who felt confident that the providers could address problems with CGMs and insulin pumps to correct any issues to help maintain their future glycemic levels (Quotation 2). Providers were also insightful about when a YA was not coping with their T1D device management and subsequently stepped in to help with decisions around care when needed (Quotation 3).

The YAs also demonstrated competence and knowledge regarding the management of their devices that was facilitated by providers who offered structured support that was targeted to each YA (Quotation 4). The YAs felt confident in the clinical competence of the providers knowing who to go to within the team when problems arose, especially when related to devices and understanding patterns in their CGM data. This competence not only supports clinical care but cultivates a supportive environment where YAs feel understood, empowered and equipped to thrive despite the challenges posed by T1D (Quotations 5 and 6).

3.1.9. Alignment

The capacity of alignment within the clinic was supported with evidence for workarounds, trade-offs and self-organizing that emerged from the data. Relevant provider and YA quotations are reported in Table 11. The level of support offered to the YAs aligned with their stage on their T1D journey. For example, a YA who has lived with T1D for most of their life could often self-manage their digital devices and required minimal support, whereas a newly diagnosed YA required more education, monitoring, and follow-up. The clinic was flexible around appointment times and appointment mode could be adapted from in person to telehealth if a YA needed between clinic visit support or if they were unable to attend in person (Quotation 1). The challenges presented by the COVID-19 pandemic facilitated the transition to online appointment modes ensuring that DTs continued to be introduced, and that their quality and safety was maintained (Quotation 2). The YAs also endorsed the convenience of telephone appointments and the reassurance that their CGM data was checked online (Quotation 3).

Flexibility and adaptation to the YAs needs occurred when devices were introduced to a YA or when glycemic patterns were sub-optimal between clinic visits. When a YA who is experienced with managing their T1D identifies patterns in their CGM data they have learned to make the necessary adjustments. Despite providers disagreeing with their choices at times, there was evidence for encouraging YA self-organization to make adaptations to their insulin pumps based on the YAs preference and need (Quotation 4).

3.1.10. Learning

Providers built on YA's existing knowledge of technological devices and listened to patient feedback when making changes (Table 12). Problems that occurred when devices were not synced properly were managed collaboratively to promote knowledge and learning. Even when the YA seemed confused, the provider allowed them to work through the problem themselves. Providers suggest compatible devices and discuss in the context of risk and safety with the YA, prior to any change. This approach encourages capacity building for the YA to manage their care via the acquisition of knowledge (Quotation 1). The YAs were able to learn from providers in the clinic about using new DTs and how to interpret glucose patterns that emerge in the CGM data and apply this knowledge at home (Quotation 2).

4. Discussion

This study examined the contribution of DTs to resilience capacity in the context of an established young adult T1D transition clinic. Through immersion in the clinic and interviews with providers and YAs, we reported how DTs are currently used to improve the quality and safety of care for YA with T1D. These included diabetes devices such as CGM and insulin pumps, communication tools, data storage and apps. Building upon this, we identified strong support for seven of the ten capacities described for resilience in healthcare (Lyng et al., 2022), that have contributed to the capacity for resilient performance of the YA clinic. We found that Leadership and Involvement emerged strongly in this case study. In the YA clinic, resilient, high-quality care is very strongly determined by the facilitation of learning and the involvement of the YA and their carers. They were required to work with the clinical team, play an important part in self-monitoring via DTs and self-care while supported by the team to develop competence. We also found that Coordination and Communication, and Competence and Risk Awareness were strongly linked with evidence for several positive patient and service adaptations that centred around Involvement. We also found evidence to support Alignment specifically where the clinic responded to challenges and adapted to YAs needs and preferences. Competent leadership, the presence of consistent staff including a transition coordinator, enabled communication, risk awareness, adaptations to YAs needs and preferences with respect to technology, and the maintenance of a positive culture for patients and staff made important contributions to the clinic's success. There was also support for the remaining three capacities with evidence for a Structured approach to the implementation of technology based on ISPAD guidelines, Learning, where YAs developed the capacity for self-care supported by providers, and Facilitators, where leaders integrated training and support into the clinic. Together, these findings highlight that the program delivered in a YA clinic demonstrates resilience enhanced by DTs to ensure that despite a challenging cohort, consistent high-quality care is delivered.

Navigating adolescence, coupled with a chronic condition such as T1D, can be challenging with treatment adherence rates reducing significantly during this time (Lotstein et al., 2013). Our study showed that the utilization of DTs such as CGM, insulin pumps, digital data storage and online transfer methods and mobile communication and apps were commonly reported within the clinics. These findings are supported by the literature as new therapies, technologies, and devices have emerged that are resulting in improved glycemic control (Wadwa et al., 2023), and quality of life (Sun et al., 2019). Additionally, adolescents and YAs are familiar with, and generally comfortable when interacting with technology, thereby offering convenience and easy access to support (Anderson and Jiang, 2018). Our results reflected that T1D care was patient centred; YAs were provided education about the benefits and risks of using DTs, were offered choice and their decisions were supported by the providers.

One of the strongest links between capacities that emerged from the data was strong Leadership and Involvement, enabling Communication and Coordination. Most of the YAs reported high levels of satisfaction with respect to the coordination of care provided by a skilled MDT, which led to a smooth transition from pediatric to adult care. The transfer of information between pediatric and adult clinics was relatively seamless and the YA did not have to explain their medical history repeatedly, therefore ensuring time efficiency. Access to a clinical coordinator via mobile communication and the ability to send CGM data

online when the YA had a concern, allowed for monitoring of their data. This process ensured that the YAs felt safe, trusting that an expert would view their data and respond to them within 24-h. The ease of arranging appointments over SMS messaging that were adaptable around the YA's schedule provided more evidence of how the clinic supports YAs in maintaining connection with the clinic and consequently ensuring they attend appointments to help maintain their glycemic control. These findings are supported by previous studies that showed that a MDT led by a clinic coordinator improves continuity of care, delivers more personalized care, improved quality of life, and outcomes (Li et al., 2021; Nordström et al., 2018), and is preferred (Carrigan et al., 2023a).

A further strong link, supported by strong Leadership and Involvement, emerged between Competence and Risk awareness. Knowledgeable and skilled providers collaborated with the YAs to ensure they were aware of the risks of not attending the clinic or maintaining safe glycemic levels, and concurrently assessed their capacity and competence for self-management of T1D care. These findings are consistent with Lyng's study (Lyng et al., 2022) whose work describe competence as a provider's ability to assess context to understand individuals' needs and preferences. Understanding the benefits of using T1D technology such as improvements in glycemic levels and adhering to international guidelines, the providers worked alongside YAs to support the uptake and management of DTs therefore supporting the potential of anticipation (Hollnagel, 2017). Risks were mitigated at the organizational level with evidence for succession plans, and informal guidelines for when short-staffed or a clinic appointment was unavailable. These findings provide evidence for how a clinic, facilitated by providers, demonstrates resilience as DTs help to support quality and safety.

Living with T1D creates a situation of uncertainty with regards to glycemic levels which can rapidly change due to exercise or food intake. Maintaining safe glycemic levels can be a high-pressure situation for some YAs and in such cases, providers could seamlessly implement alignments to achieve positive outcomes. The clinic offered a degree of flexibility and adaptation with respect to use of devices and collaborated with the YA to ensure that their clinical and non-clinical needs were met (Alignment; Lyng et al., 2022). This included their ability to manage their devices with adjustments or workarounds made when indicated, thereby increasing their responding potential (Hollnagel, 2017). These findings are consistent with Anderson and Jiang (2018) who describe that adaptations are needed in response to misalignment. In our study we see some evidence for misalignment where there is a high demand for YAs to self-manage their T1D and a reduced capacity to do so due to a lack of competence. As the clinic was able to adapt in response to these challenges, we see evidence for the learning potential as suggested by Hollnagel (2017).

The use of DTs within the clinic invites the YA to co-produce their care. Co-production of health on micro-system level is a service delivery that involves the mutual collaboration between individuals living with a condition and professional providers caring for the condition (Vennik et al., 2016) . Our work provides evidence for the empowerment of YAs to self-monitor their CGM data knowing they have an open communication channel with the clinic should concerns arise. Crucially, co-production was a dynamic process that adapted as the YAs needs and preferences for devices changed.

Although most YAs and providers perceived digital communication technologies and apps beneficial, not all the participants chose to adopt diabetes technologies such as CGM and insulin pumps. Several reasons were identified such as concern of the device coming off at work and alarm fatigue, potentially increasing their T1D burden of care. The providers used their expertise and competence to help the YAs overcome these barriers, by educating YAs about the benefits, while taking a graduated approach to implementation, often offering a trial period. The providers in both clinics adhered to the ISPAD guidelines that recommends that YAs be offered the most advanced technology available, ensuring that the decision is appropriate given the YA's circumstances (Sherr et al., 2022).

It is important to note that several barriers persist in accessing diabetes technology, creating significant equity and accessibility issues. For example, in Australia, most children access an insulin pump through their family's private healthcare insurance. If the family do not have private health insurance, they can apply for a pump via the Federal Government Juvenile Diabetes Research Foundation (JDRF) pump scheme. This scheme is means tested on the parental income (limited up to a combined family annual income of up to $117,340 AUD/annum) and if they meet financial criteria for a pump only one brand of pump is available through the scheme. Unfortunately, this reduces choice, especially for YAs who are unable to afford access to technology. Despite these known barriers, all the providers and almost all the YAs in the current study endorsed the benefits of using devices and DTs to safely manage T1D. Specifically, the automation of digital information transmission, rapid information transfer and ease of use.

5. Limitations and future directions

Although our case study shows how DTs have been integrated into the T1D YA service model of care and contributed to resilience capacity, these findings must be interpreted with caution. The evidence that the clinic has maintained positive clinical outcomes across 21 years cannot be attributed uniquely to DTs as these have mostly emerged over the last decade. There are other non-DT related capacities at play such as leadership and coordination as our results have demonstrated. A further limitation is that the findings may not be generalizable to other settings. The pediatric and YA clinics are in tertiary, urban hospitals which are well resourced and have appropriately resourced staff, compared with regional services. Australia has the resources to offer DTs to all people with T1D as they are subsidised by the government, which is not the case in other countries. However, those over 18 years, from lower socio-economic areas, often lack access to private health insurance, denying ready access to automated insulin delivery uptake of technology; and those in the lowest income quintile are also less likely to use CGM (Lomax et al., 2023; Sherr et al., 2016). Future work that examines a broader range of clinics would be beneficial, especially those in non Organization for Economic Co-operation and Development (OECD) Category 1 countries (Organization for Economic Co-operation and Development, 2021), specifically to identify the barriers and enablers regarding access to DTs. Finally, despite recruiting small sample sizes, data saturation for providers and YAs was reached. Importantly, our data was collected across a range of medical providers and YA ages/T1D experiences, at both sites, improving the validity of our findings.

6. Conclusion

The transition program is an excellent example of a model of care with evidence of resilience capacity leading to resilient performance, and provides an opportunity to study the contributions of DTs to enhance the capacity for the resilience of outpatient healthcare services in-depth. Through examination of resilient capacities (Lyng et al., 2022), our research has provided evidence for how DTs in the T1D YA clinic relates to the ten capacities of resilient healthcare. The findings also support the four mechanisms underpinning these capacities; *monitoring, anticipation, responding, and learning* to adapt to YA's preferences and needs with respect to technology (da Rosa et al., 2021; Hollnagel, 2017). Going beyond the current study, understanding the underlying mechanisms that support the transition clinic may be useful for YAs with other chronic health conditions transitioning from pediatric to adult care.

CRediT authorship contribution statement

Ann Carrigan: Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **D. Jane Holmes-Walker:** Writing – review & editing, Writing – original draft, Validation.

Kaye Farrell: Writing – original draft, Validation. **Ann M. Maguire:** Writing – review & editing, Writing – original draft, Validation. **Hilda Bø Lyng:** Writing – review & editing, Writing – original draft, Validation, Formal analysis, Data curation. **Siri Wiig:** Writing – review & editing, Writing – original draft, Supervision, Formal analysis. **Veslemøy Guise:** Writing – original draft, Validation, Formal analysis. **Janet C. Long:** Writing – review & editing, Writing – original draft, Validation, Formal analysis, Data curation. **Louise A. Ellis:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation. **Shalini Wijekulasuriya:** Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Putu Novi Arfirsta Dharmayani:** Writing – original draft, Investigation, Formal analysis, Data curation. **Nehal Singh:** Writing – original draft, Formal analysis, Data curation. **Zach Simone:** Validation, Methodology, Conceptualization. **Elizabeth Davis:** Validation, Supervision, Funding acquisition. **Timothy W. Jones:** Validation, Supervision, Funding acquisition. **Jeffrey Braithwaite:** Writing – review & editing, Writing – original draft, Supervision, Funding acquisition. **Yvonne Zurynski:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

For data collection, we acknowledge the support of the providers and patients who gave up their time. The study was funded by the JDRF Australia Global Centre of Excellence Grant (5-SRA-2021-1088-M-X) and supported by the Research Council of Norway from the FRIPRO TOPPFORSK program, grant agreement no. 275367. The University of Stavanger, Norway; NTNU Gjøvik, Norway.

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