

**A Qualitative Analysis of Resources to Diminish Barriers to Physical
Activity in Young Adults with Type 1 Diabetes**

Carly Medwin

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Department of Nutrition

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Dr. Elizabeth Mayer-Davis, PhD

Advisor

Angelica Cristello

2nd Reader

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Abstract

Background: Exercise is an important glycemic control and weight management technique for those with type 1 diabetes (T1D), yet there are barriers such as fear of hypo- and hyperglycemia as well as the lack of structured guidelines for safe exercise that keep approximately 60% of these individuals from participating in regular physical activity.¹ The goal of this project is to understand what resources and kinds of support individuals with T1D are looking for to assist with their exercise routines and diminish the barriers they face while exercising.

Methods: We recruited 29 adults aged 18-40 who had T1D for more than 1 year and were not pregnant to participate in virtual focus group discussions. The theoretical framework for this study (Figure 1) guided the survey and focus group discussions for among young adults with T1D to elicit their perspectives about whether these resources would support regular and safe exercise with T1D.

Results: For each topic prompted in the focus group discussions, we found two main themes that included specific reasons for not regularly participating in exercise or reasons why specific resources would or would not be useful. Personalization and accessibility of resources as well as fear of using resources due to previous negative experiences and demanding suggestions were identified as cross-cutting themes across all focus group topics.

Conclusions: The perspectives we collected suggest that barriers to exercising with T1D and the qualities of ideal resources to combat them are consistent with the existing literature,^{4,5,6,7} but more research needs to be conducted regarding the realistic potential and personalization of resources. Participants noted many barriers to using such resources that varied depending on their previous life experiences with T1D. This raises the need for user support regarding such

resources at the time of diagnosis to limit preventable barriers that arise from navigating exercise on one's own without the appropriate amount and specificity of support.

Introduction

Overview of Type 1 Diabetes

Type 1 diabetes (T1D) is a chronic autoimmune disease that is caused by the destruction of the insulin producing β cells of the pancreas, resulting in a decrease of insulin production that evokes the need for exogenous insulin for survival.¹ Without sufficient insulin, this disruption of the body's blood glucose regulation causes hyperglycemia, which is a state of high blood glucose levels because glucose cannot effectively enter the cells.¹ This is in contrast to the pathology of type 2 diabetes (T2D), in which the pancreatic β cells are still partially functioning but a combination of defects in insulin secretion and cellular response to insulin results in insulin levels that are not sufficient to compensate for this lack of cellular response.² Insulin is an anabolic hormone that maintains the balance of glucose in the blood by stimulating the movement of glucose transporters to facilitate glucose entry into cells primarily for energy production.¹ When insulin is not present in T1D to allow for this seamless conversion of food into energy the body must utilize stored fat for energy instead.¹ This process manifests in symptoms such as weight loss and elevated ketone levels in the blood.² Because the tissues are not receiving enough glucose due to this lack of insulin, the endocrine system assumes that the body is in a state of starvation and releases glucagon to stimulate gluconeogenesis.¹ This process further leads to increased blood glucose levels that still cannot enter the cells without insulin and has no other option but to leave the body, which is reflected in sweet-smelling breath and dehydration associated with frequent urination in undiagnosed patients with T1D.²

The ADA cites that individuals with a fasting plasma glucose of 126 mg/dl or higher have diabetes, compared to a typical fasting plasma glucose of less than 100 mg/dl.³ Other criteria for diagnosis includes an HbA_{1C} of 6.5% or higher or a plasma glucose test that reads 200 mg/dl or higher in combination with the symptoms explained above.³ Approximately 1.6 million Americans have T1D, including 64,000 diagnoses each year.⁴ Diagnoses most frequently occur during childhood or adolescence, but T1D can develop at any age.⁵ The exact causes for the disease are unknown, but recent evidence points to a possible combination of viral infection, environmental factors, and predisposed genes that may result in impaired β cell function.⁶ This also means that there are no strategies that can be taken to prevent the onset of T1D.⁵ A systematic review of T1D related studies concluded that the incidence and prevalence of T1D are both increasing around the world, although there is no known preventative treatment or cure.⁷ Therefore, specific and frequent treatment strategies are critical to living a long and quality life with T1D.

Treatment and Management Options for Type 1 Diabetes

The most vital treatment option for patients with T1D is the calculated use of synthetic insulin. Insulin has transformed T1D from a terminal to a treatable disease since its discovery in 1922.⁸ Since then, discoveries have resulted in options and varying methods for how to use this insulin, including multiple daily injections from insulin pens or needles, continuous subcutaneous insulin infusions in the form of an insulin pump, or a combination of the two.⁸ Although studies have found that patients with T1D who use insulin pumps have lower HbA_{1C} values than do those who use multiple daily insulin injections, widespread accessibility of this expensive technology is still lacking as a result of healthcare disparities across the world.⁹

Because synthetic insulin is delivered subcutaneously through adipose, it cannot exactly mimic the functions of insulin in the hepatic portal circulation in those without diabetes.² This delivery method means that insulin bypasses the homeostatic feedback regulation that typically maintains the proper amount of insulin necessary in circulation.¹ Therefore, there is a need for long-acting insulin to mimic the actions of physiological insulin between meal times or during fasting periods combined with the need for fast-acting insulin right before or during meal times depending on the type of food consumed and the number of carbohydrates in it.⁸ It can take anywhere from fifteen minutes to an hour for these kinds of insulin to act, making blood glucose levels more difficult to manage as a result of these uncontrollable delays in action.⁸ An individual's specific uptake of insulin also varies greatly and is dependent on a variety of variables such as sex, temperature, injection depth, other hormone levels, and body composition, which adds to the difficulties in predicting blood glucose levels and insulin effectiveness.⁹

However, insulin pumps aim to get as close as possible to the normal physiologic functions of insulin by constantly providing small amounts of insulin to the individual with diabetes, who still has to bolus or increase the amount of insulin given depending on the type of event or food consumed.² To do this, the T1D patient has to have sufficient knowledge about the amount of carbohydrates in the foods they eat and be aware of options that will adjust their blood glucose levels in different ways. The individual with T1D must couple the use of the abovementioned technology with the use of a lancet to take a blood sample from a finger prick and provide blood glucose level readings from a lancing device or a continuous glucose monitor (CGM) that can read blood glucose levels and provide warnings to patients about the increase or decreasing pattern of their blood sugar levels in the moment as well as alarms for instances of abnormally high or low blood sugar. Pharmacologic treatments such as Metformin, Pramlintide,

and blood pressure medications are other options to assist with the management of blood glucose levels.¹⁰ It is apparent that technological advances have significantly assisted in the management of the disease, but research is ultimately working to create an artificial pancreas with full physiological insulin activity which would ideally cure the disease.¹¹

Correct use of these treatment protocols can bring the disease significantly under control by bringing blood glucose levels within ranges normally attained by individuals without T1D. The proper education about all of this technology is necessary for the correct and tight regulation of blood sugar levels. Without utilizing a combination of these strategies every day and as specifically as possible, major health complications can arise.

Acute complications related to Type 1 Diabetes

The most common and feared acute health complication related to improper management of blood glucose levels in individuals with T1D is hypoglycemia.¹² Hypoglycemia typically occurs in individuals with T1D when too much insulin is introduced, leading to blood glucose levels below 70 mg/dL.¹³ Levels this low result in the release of epinephrine, which results in symptoms such as shaking, anxiety, sweating, irritability, dizziness, and confusion.¹² If this episode is ignored or not controlled with the consumption of fast-acting carbohydrates, the brain will not receive enough glucose and energy for proper functioning which will lead to the most dangerous symptoms.² Severe prolonged hypoglycemia can result in seizures, coma, or death and requires immediate medical attention for proper recovery.¹²

Most patients with T1D can expect to experience two episodes of symptomatic hypoglycemia each week.¹² These instances keep such individuals from reaching optimal blood glucose levels and also deter them from accurately utilizing insulin pumps or other technologies that work to lower blood glucose levels.¹⁴ There is particular concern of nocturnal hypoglycemia,

as people with T1D are less likely to sense warning symptoms while they are asleep.¹⁵ Recurrent episodes of hypoglycemia are known to impair brain function and autonomic nervous system activity.² Studies suggest that patients with T1D fear hypoglycemic episodes just as much as they fear long-term complications such as retinopathy or kidney disease.¹²

Improper use of insulin can also lead to prolonged hyperglycemia, and a buildup of acidic ketones from lipolysis in the absence of insulin in circulation will eventually result in diabetic ketoacidosis which will lower the pH of blood and change the functionality of thousands of enzymes that are essential for life.¹ Mental health disorders are a psychosocial condition associated with T1D, since individuals with T1D are significantly more likely to have depression or an eating disorder compared with those who do not have T1D.¹⁶ Each of these conditions can detrimentally affect T1D management.

Chronic complications related to Type 1 Diabetes

Over time, poorly managed blood glucose levels can result in microvascular and macrovascular complications. Diabetic neuropathy, nephropathy, and retinopathy are considered microvascular complications and are prevalent in many individuals with T1D who also have poor blood glucose level control.¹⁷ Excess glucose in circulation can eventually damage nerves, break down capillaries that supply extremities with nutrients, and deposit in especially vulnerable blood vessels in the retina, kidneys, and other organs.¹⁸ These microvascular complications can manifest in nerve pain, microalbuminuria, renal failure, hemorrhages in the retina, blindness, and need for foot amputation.¹⁹ Oxidative stress will exacerbate potential cell damage from prolonged hyperglycemia.¹⁸ Furthermore, excess blood glucose in circulation in combination with other factors such as dyslipidemia is what makes people with T1D ten times more likely to develop macrovascular complications from cardiovascular disease such as

myocardial infraction, stroke, or angina than people without diabetes.² Although not as much is known about the manifestation of cardiovascular disease in T1D compared to what is known about the risk of cardiovascular disease in T2D, individuals with T1D see macrovascular complications much earlier in life than the general population.¹⁹ Diabetes is now considered to be a coronary artery disease risk equivalent, and people with T1D also have a higher risk of death from ischemic heart disease compared to those without T1D.¹⁸ All of these events greatly contribute to the 14.4 billion dollars that T1D costs the United States each year.²⁰ Studies have shown that reducing HbA1c levels in those with T1D can delay the onset or progression of microvascular complications, so proactive steps can and should be taken to minimize the risk of these complications associated with T1D.¹⁷

Importance of Exercising with Type 1 Diabetes

In combination with the appropriate/correct pharmacological use of insulin, regular physical activity and a healthy diet are important factors in improving both life expectancy and quality of life for people with T1D. Physical activity has been long known to improve cardiometabolic health, lung efficiency, body weight, muscle and bone strength, lipid levels, and mental health.²¹ Most significantly, regularly planned exercise improves insulin sensitivity, making cells more receptive to the presence of insulin.²² This is especially important for individuals with T1D as improved insulin sensitivity not only increases the amount of glucose that enters the cells for energy use but also diminishes the amount of synthetic insulin necessary for the T1D patient to manage his or her blood glucose levels.²² Aerobic exercise also allows for glucose to be taken up into the muscle cells through insulin-independent mechanisms during and after exercise, which also decreases the quantitative need for insulin.²³ Additionally, T1D patients can decrease their risk of retinopathy, diabetic ketoacidosis, and cardiovascular disease

by incorporating regular exercise into their routine.²³ As of 2018, more than half of the T1D population in the United States is overweight or obese, so exercise can be utilized to combat the poor health outcomes of those conditions as well.²⁴ Recently, evidence even points to the protective effects of exercise as it interferes with the immune system's function specifically as it relates to autoimmune diseases such as T1D and may reduce the inflammation that these diseases create.²⁵

The ADA recommends individuals with diabetes to participate in at least 150 minutes of moderate or vigorous physical activity each week, with no more than 2 consecutive days of no physical activity.²¹ Specifically, resistance activities are recommended at least twice a week to incur excess benefits such as improved bone health and glucose stability.²⁶ Although detailed guidelines exist explaining the types, duration, and methods of exercises that should be incorporated into the lifestyles of patients with T2D, the literature is lacking in these specifications for patients with T1D.²¹ Regardless of the plethora of benefits from regular exercise, approximately 60% of patients with T1D do not incorporate any structured exercise into their routines.²⁴ Research has been done and initiatives have been taken to determine why this is the case, and a variety of reasons have been found.

Barriers to Exercising with Type 1 Diabetes

Barriers to participating in regular exercise for the general population include lack of time, energy, motivation, social support, skill, knowledge, financial resources, and facilities or sufficient space.²⁷ Additionally, fear of injury or discomfort in social exercise environments can deter many individuals from keeping exercise a normal part of their routines. These barriers still exist for individuals with T1D, although serious health complications can also arise if blood glucose levels are not properly managed throughout physical activity. Studies have constantly

found that fear of hypoglycemia is the leading barrier to participating in physical activity among patients with T1D.^{14,27,28} Physical activity can increase risk of hypoglycemia for up to 24 hours after the activity occurs, since glucose stores are rapidly used for energy and hormone shifts and stress from exercise make blood glucose levels especially unpredictable.²⁹ Exercise can immediately cause elevated blood sugar levels and insulin corrective strategies may overestimate the need for insulin, therefore dropping blood glucose levels dangerously low.²⁹ Patients with T1D have reported feelings of loss of control of their blood glucose levels during exercise, which can further lead to decreased motivation and willingness to participate in exercise.³⁰

Insulin therapies cannot automatically account for the rapid changes in blood glucose levels that occur during physical activity, which is why patients with T1D need to be extra aware of their glucose levels prior to, during, and after physical activity.³⁰ This high-maintenance management technique poses difficulties especially for those who do not have access to a CGM or similar technology to read blood glucose levels as well as those who cannot utilize these therapies during physical activities such as sport games and competitions. Additional techniques to manage blood sugar levels during exercise include reducing the amount of insulin introduced to the body before starting exercise or having fast-acting carbohydrate sources available to consume if hypoglycemia does occur.²⁴ All of these strategies place stress on the individual and require additional caution which can lead many of those with T1D to stray away from participating in regular physical activity.

Because of the multitude of strategies that have to be highly specialized to an individual with T1D to assist in safe regular physical activity, there is a lack of detailed guidelines in place on how to exercise safely with T1D. The ADA recommends implementing extra carbohydrate consumption, reducing insulin input, and frequent blood glucose checks while exercising, but

more specific knowledge of the individual's experience with T1D is necessary to make detailed suggestions.²¹ The long list of barriers to exercising with T1D creates an anxious and unsafe attitude about the idea of exercise, which is why various resources are necessary to lead to a shift in perspective. Resources can be used to ease the process of incorporating safe exercise with T1D into a daily routine, as these kinds of encouragement can help the individual learn what exercise strategies work best for his or her body in a supportive environment.

Pre-Existing Resources to Assist with Exercising with Type 1 Diabetes

The importance of regularly exercising with T1D as well as the barriers that prevent it are both clear, but there are gaps in the literature of how to solve this pertinent issue. We suggest that individuals with T1D can seek help from a variety of resources to improve their education and bolster their feelings around safe and regular exercise. Some resources that currently exist and are specific to exercising with diabetes include mobile apps to track blood glucose patterns, exercise programs made for those with T1D, support from health care professionals such as endocrinologists, physical therapists, and nutritionists, and T1D-related support groups.

Glucose Buddy, *Glucose – Blood Sugar Tracker*, *mySugr*, and *One Drop* are all examples of mobile apps that have been created specifically for individuals with diabetes.^{31,32,33,34} Specific details can be found on the iOS App Store or Google Play Store, but the overall purpose of these apps is to track blood glucose level patterns and other healthy habits that can include dietary intake, exercise routines, and medication compliance. These apps can be linked to a CGM to follow blood glucose level trends before, during, and after exercise and can therefore lead the user to create specific strategies to improve blood glucose level maintenance and overall quality of the exercising experience in the future.

Because there are very few apps that are specifically targeted towards individuals with T1D who want to participate in safe exercise, UNC Chapel Hill and NC State are currently collaborating to create an app by the name of HEDRA that will offer specialized, real-time strategies for safe exercise dependent on an individual's blood glucose level patterns from CGM data.³⁵ Examples of these strategies may include suggestions for insulin dosing, carbohydrate intake or time and type of exercise. The goal is to offer a highly personalized experience for the user that will ultimately improve overall participation in and attitudes surrounding exercise among individuals with T1D.³⁵

We also suggest that personalized workout routines will be useful in supporting safe exercise habits among those with T1D. Examples of these could be exercise plans that are specific to an individual and created by a personal trainer with experience related to exercising with T1D or *Glucose Zone*, an exercise program that is created specifically to assist individuals with type 1 or type 2 diabetes with safe and efficient exercise.³⁶ *Glucose Zone* also offers a database of on-demand workouts in which the subscriber can watch a variety of workouts while hearing strategies in real time about how to manage his or her blood glucose levels and spot symptoms of hypoglycemia.³⁶

The combination of one or more of these resources with the support of an endocrinologist, physical therapist, or nutritionist could also be useful in supporting safe exercise habits with T1D. The educational perspective these professionals can offer can be helpful in using the patient's lifestyle habits to create an enjoyable approach to exercise. Ideally, this resource would expand on the broad guidelines in place for exercising with T1D to make them more applicable to the T1D patient.

Finally, the use of support groups made of T1D patients or related family members can diminish barriers to exercising safely with T1D. Whether virtual, in person, or on social media, support groups offer a unique environment of community and belonging where individuals with T1D can share personal stories that may be invaluable to another person's experience with T1D. This resource may be most useful for individuals with T1D who are just beginning to start incorporating exercise into their routines or have questions about a management technique related to safe exercise.

Specific Aims

Aim 1: Assess the barriers that young adults with T1D experience in relation to exercising.

1a. Discern if these barriers are specific to individuals with T1D by forming a discussion around the preconceived barriers to exercising with T1D and asking participants which barriers, if any, are the most concerning when considering exercise.

Aim 2: Determine which resources including, but not limited to, mobile apps to track blood glucose patterns, exercise programs made for those with T1D, support from health care professionals such as endocrinologists, physical therapists, and nutritionists, and T1D-related support groups would support young adults with T1D who want to safely exercise.

2a. Assess responses from participants to identify the usefulness of these resources and compare feedback between young adults with T1D who frequently exercise and those who do not.

Methods

Recruitment

We aimed to recruit 32 adults aged 18-40 who had T1D for more than 1 year and were not pregnant. Potential subjects were recruited virtually by spreading study information to local T1D organizations such as Type 1 Tarheels at UNCCH and College Diabetes Network Chapter of NC, as well as posting recruitment information in Facebook groups related to T1D and exercise and on Research for Me @ UNC. The recruitment materials contained a short summary of what participants would be asked to do, eligibility criteria, and compensation information. Majority of the individuals in these online groups met the eligibility criteria for the study, but the potential subjects decided if they wanted to participate by contacting a research team member (CM).

Once initial contact was made, 37 potential subjects were sent a personalized link to a short Qualtrics survey with embedded consent. The survey asked about eligibility criteria, race, gender, insulin therapy use, and time spent participating in vigorous, moderate, and walking activities over the last seven days. Physical activity participation in the previous week was asked in the hopes of separating the potential subjects into two groups: those who met the ADA physical activity recommendation of 150 minutes of moderate to vigorous activity per week and those who did not meet this recommendation.³ Potential subjects were also asked to report any resources they had used in the past to assist with their exercise routines and whether they would like to exercise more often or about the same amount in the future.

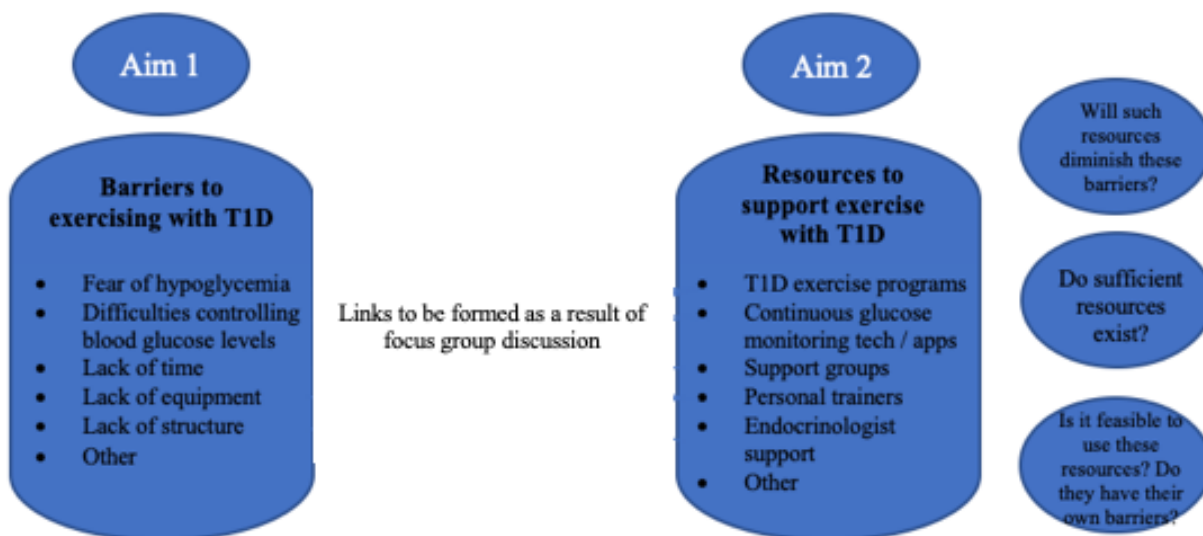
31 potential subjects completed the eligibility survey and were then emailed a consent form which they were asked to virtually sign and return, as well as a scheduling tool to organize

the focus group discussions held on Zoom. 29 participants returned the consent forms and participated in our focus groups.

Focus Groups

A focus group setting was chosen to obtain data because the research team felt it would best answer the subtleties of the research question since it provided a relaxed environment to offer opinions and anecdotes with the hope of coming to a group consensus among individuals with shared characteristics. The virtual focus groups were held on zoom on 11/30/21, 1/5/22, 1/30/22, and 2/13/22. Each focus group lasted approximately 1 hour and 15 minutes. The focus group discussions were facilitated by a script that included questions about preconceived barriers to exercising with T1D and the effectiveness of four resources (mobile apps, exercise programs, health professionals, and support groups) to diminish these barriers, but the participants were free to shift the conversation and bring up any topics they wanted. The discussions were audio recorded for anonymous data recording purposes. Subjects were not required to share or answer anything if they chose not to.

The theoretical framework for this study (Figure 1) guided the survey and focus group discussions for among young adults with T1D to discern if these resources support regular and safe exercise with T1D.



Transcription

The audio recordings from all four focus groups were transcribed by a member of the research team (CM) and reviewed by other members (CC, EW) for accuracy.

Data Analysis

Participant quotations were organized into deductive categories based on topics that researchers prompted during the focus group discussions: barriers to exercising with type 1, apps as a resource, structured workouts as a resource, health professional support as a resource, and support groups as a resource. In each of these topics, we found two themes that included specific reasons for not regularly participating in exercise or reasons why specific resources would or would not be useful. Within some of these themes, subthemes were found that further reflected the major perspectives of participants. Each member of the research team (CM, CC, EW) worked together to use a matrix method to systematically organize data and establish a consensus in coding and themes. This process was repeated for each focus group discussion to come to a final consensus of topics with themes, subthemes, descriptive summaries, and illustrative quotes to describe the findings of the four focus groups. The research team then looked at the total

collection of data through an inductive approach and found overarching and cross-cutting themes that presented across all of the topics in our focus group discussions.

Data Security

As soon as transcriptions were completed, the audio recordings were destroyed. Each participant was labeled with a unique number in the analysis so that no identifiable characteristics would be distinguishable.

Manuscript for Diabetes Technology and Therapeutics

A Qualitative Analysis of Resources to Diminish Barriers to Physical Activity in Young

Adults with Type 1 Diabetes

Carlyssa J. Medwin, Angelica Cristello, Charlotte D. Cunningham, Emily Wright, Elizabeth J. Mayer-Davis

Running Title: Resources to Assist Exercising with T1D

Keywords: Type 1 Diabetes, Exercise, Physical Activity, Resources

Abstract:

Background: Exercise is an important glycemic control and weight management technique for those with type 1 diabetes (T1D), yet there are barriers such as fear of hypo- and hyperglycemia as well as the lack of structured guidelines for safe exercise that keep approximately 60% of these individuals from participating in regular physical activity (PA).^{1,2} The goal of this project is to understand what resources and kinds of support individuals with T1D are looking for to assist with their exercise routines and minimize the barriers they face while exercising.

Methods: We recruited 29 adults aged 18-40 who had T1D for more than 1 year and were not pregnant to participate in virtual focus group (FG) discussions. These discussions were facilitated by a script that included questions about preconceived barriers to exercising with T1D and the effectiveness of four resources (mobile apps, exercise programs, health professionals, and support groups) to diminish these barriers.

Results: For each topic prompted in the FG discussions, we found two main themes that included specific reasons for not regularly participating in exercise or reasons why specific resources would or would not be useful. Cross-cutting themes across all FG topics included

personalization and accessibility of resources as well as fear of using resources due to previous negative experiences and demanding suggestions.

Conclusions: The perspectives we collected suggest that barriers to exercising with T1D and the qualities of ideal resources to combat them are consistent with the existing literature,^{3,4,5,6} but more research needs to be conducted regarding the realistic potential and personalization of resources. Participants noted many barriers to using such resources that varied depending on their previous life experiences with T1D. This raises the need for user support regarding such resources at the time of diagnosis to limit preventable barriers that arise from navigating exercise on one's own without the appropriate amount and specificity of support.

Introduction:

Whether it is due to the lack of detailed and specialized guidelines for safely exercising with Type 1 Diabetes (T1D) or the possibility of hypoglycemia during exercise causing dangerous complications, an estimated 60% of T1D patients do not participate in regular physical activity (PA).¹ The American Diabetes Association recommends adults with T1D to participate in at least 150 minutes of moderate to vigorous PA per week because exercise provides a multitude of benefits to individuals with T1D including improved cardiovascular health, reduced levels of body adiposity, and increased overall well-being.^{7,8,9} Most significantly, exercise improves insulin sensitivity and therefore reduces the amount of necessary synthetic insulin.¹⁰ Additionally, T1D patients who regularly exercise are known to have improved glucose control and a lowered risk for microvascular and macrovascular complications such as diabetic neuropathy, retinopathy, myocardial infraction, and cardiovascular disease.^{7,11} Even with these advantages the majority of T1D patients do not regularly participate in PA, possibly due to the fact that blood glucose levels tend to fluctuate irregularly throughout exercise and cause an

increased necessity for blood glucose level control in addition to a strong fear of hypoglycemia during or after exercise.^{1,2} As such, exercising with T1D presents additional barriers along with those that are already common in the general population when attempting to create an exercise routine: lack of time, equipment, or motivation.⁴

Although the importance of exercise and the barriers to it for those with T1D is well known, little action has been taken to ease this process of exercising safely and frequently with T1D. We propose resources as a method to minimize the barriers to exercising with T1D and aimed to investigate the perspectives of individuals with T1D who would be using such tools in a focus group (FG) setting to understand the barriers that they face in relation to exercise and the kinds of support they are looking for. We presented and aimed to gain feedback about four resources to assist in the safety of exercise routines with T1D: mobile apps to track blood glucose level patterns (such as *Glucose Buddy*¹², *Glucose Tracker*¹³, *MySugr*¹⁴, and *One Drop*¹⁵), structured workouts made for those with T1D (including workouts designed by a personal trainer or exercise program such as *Glucose Zone*¹⁶), T1D-related support groups, and support from a combination of health care professionals such as endocrinologists, nutritionists, or physical therapists. These four types of resources span the digital, social, and educational tools that exist to assist with exercising with T1D and similar kinds of encouragement have been shown to promote PA levels among the individual and community.¹⁷ Ideally, the perspectives we elicit can aid in the initial development process of resources that are designed to assist in decreasing the prevalence of T1D patients who do not regularly exercise by minimizing the present barriers, thereby assuring these individuals in the safety of their exercise routines.

Methods:

This study was approved by the Institutional Review Board at the University of North Carolina at Chapel Hill.

Recruitment

We aimed to recruit 32 adults aged 18-40 who had T1D for more than 1 year and were not pregnant. Potential subjects were recruited virtually by sending study information to local T1D organizations such as Type 1 Tarheels at UNCCH and College Diabetes Network Chapter of NC, as well as posting recruitment information in Facebook groups related to T1D and exercise and on Research for Me @ UNC. All participant and researcher communications took place virtually for the purposes of mitigating COVID-19 concerns and reaching a wider variety of participants compared to those who would be able to attend locally. Potential subjects decided if they wanted to participate by contacting a research team member (CM).

Once initial contact was made, 37 potential subjects were sent a personalized link to a short Qualtrics survey with embedded consent. The survey asked about eligibility criteria, race, gender, insulin therapy use, and time spent participating in vigorous, moderate, and walking activities over the last seven days. These questions were asked with the intention of separating the potential subjects into two groups: those who met the ADA PA recommendation of 150 minutes of moderate to vigorous activity per week and those who did not meet this recommendation.⁸ We aimed to use this criteria to stratify groups in order to create a more homogenous group of participants who had similar experiences with T1D and exercise so they would both feel more comfortable in providing quotations and reach a stronger group consensus.¹⁸ Potential subjects were also asked to report any resources they had used in the past to assist with their exercise routines and whether they would like to exercise more often or about the same amount in the future to further assess their life experiences with T1D and PA.

31 potential subjects completed the eligibility survey and were then emailed a consent form which they were asked to virtually sign and return, as well as a scheduling tool to organize the focus group discussions held on Zoom. 29 participants returned the consent forms and participated in our focus groups.

Focus Groups

FGs are the best choice for data collection in this study because they offer unique perspectives that arise on their own due to the of interaction of participants in the discussion; this aspect of FGs allowed us to explore the aims of this project in a more thorough way than if we were to use a questionnaire or individual interviews.¹⁸ We wanted to provide a small yet adequate environment where participants would feel comfortable sharing their thoughts and hoped to find shared opinions and experiences that would strengthen the usefulness of these quotations.¹⁹ Four FG of 6-8 participants met on Zoom to account for all responding participants within the timeline of the study. The discussions were facilitated by one moderator (CM) who wrote and used a script that included questions about preconceived barriers to exercising with T1D and the effectiveness of four resources (mobile apps, exercise programs, health professionals, and support groups) to diminish these barriers, but participants were free to shift the conversation and bring up any topics they wanted. The script was written with the guidance of a preliminary study conducted in 2020 which used FGs to understand the opinions of individuals with T1D about a mobile health app to assist with exercising. We chose such questions to target the project aims and initiate the discussion with perspectives on why exercising with T1D is difficult so that participants could keep this in mind as resources were introduced. The discussions were only audio recorded for anonymous data purposes.

Transcription

The audio recordings from all four focus groups were transcribed by a researcher (CM) and reviewed by other researchers (CC, EW) for accuracy.

Data Analysis

Each member of the research team (CM, CC, EW) worked together to use a matrix method to systematically organize data and establish a consensus among coding and themes. This method allowed all researchers to look at all of the data in an accessible and straightforward manner and also promoted collaboration and combination of interpretations that resulted in a robust/comprehensive analysis. Participant quotations were organized into deductive categories based on topics that researchers prompted during the FG discussions: barriers to exercising with type 1, apps as a resource, structured workouts as a resource, health professional support as a resource, and support groups as a resource. In each of these topics, we found two themes that included specific reasons for not regularly participating in exercise or reasons why specific resources would or would not be useful. Within some of these themes, subthemes were found that further reflected the major perspectives of participants. This process was repeated by each research team member and for each FG discussion to eliminate discrepancies and come to a final consensus of topics with themes, subthemes, descriptive summaries, and illustrative quotes to describe all findings. The research team then looked at the total collection of data through an inductive approach and found overarching and cross-cutting themes that presented across all of the topics in our FG discussions.

Data Security

As soon as transcriptions were completed, the audio recordings were destroyed. Each participant was labeled with a unique number in the analysis so that no identifiable characteristics would be distinguishable.

Results

Table 1 details the characteristics of participants in each focus group. All participants used either an insulin pump or daily insulin injections.

Table 1. Characteristics of Participants

Characteristic	All participants n=29	Focus Group 1 n=8	Focus Group 2 n=7	Focus Group 3 n=8	Focus Group 4 n=6
Demographic Characteristics					
Age, years; mean (SD)	24.7 (5.4)	25 (2.7)	28.4 (8.5)	23.3 (3.1)	21.8 (4.3)
Female gender; n (%)	19 (65.5)	1 (12.5)	5 (71.4)	7 (87.5)	6 (100)
Race/Ethnicity; n (%)					
Non-Hispanic White	19 (65.5)	0 (0)	7 (100)	6 (75)	6 (100)
Black or African American	9 (31)	8 (100)	0 (0)	1 (12.5)	0 (0)
Asian or Pacific Islander	1 (3.4)	0 (0)	0 (0)	1 (12.5)	0 (0)
T1D Characteristics					
Years with T1D; mean (SD)	9.7 (7.2)	6.8 (0.7)	15.9 (7.4)	15.1 (5.8)	18.7 (7.7)
Insulin pump use; n (%)	15 (51.7)	0 (0)	5 (71.4)	5 (62.5)	5 (83.3)
Routine use of CGM; n (%)	22 (75.9)	6 (75)	6 (85.7)	5 (62.5)	5 (83.3)
Exercise Characteristics					
PA in the last week, minutes; mean (SD)	141.4 (130.4)	189.4 (68.7)	47.9 (26.7)	105 (70)	235 (228.9)
Exercised more than 150 min/week; n (%)	10 (34.5)	4 (50)	0 (0)	2 (25)	4 (66.7)
Used any resources before; n (%)	22 (75.9)	7 (87.5)	5 (71.4)	6 (75)	4 (66.7)
Want to exercise more often; n (%)	22 (75.9)	8 (100)	7 (100)	4 (50)	3 (50)

Figure 1 shows the summary of themes and subthemes that we aimed to receive data for, which will be discussed further below.

Figure 1. Summary of Deductive Themes and Subthemes

<p>Barriers to Exercising with T1D</p> <ul style="list-style-type: none"> • Frustration due to exercising with non-T1D related concerns • Frustration due to exercising with T1D related concerns <ul style="list-style-type: none"> ○ Necessity of planned workouts with T1D ○ Unpredictability of blood glucose levels with T1D ○ Concerns related to overexerting oneself
<p>Apps as a Resource</p> <ul style="list-style-type: none"> • Apps that gave suggestions would be helpful • Apps do not support general lifestyle routines <ul style="list-style-type: none"> ○ Unfamiliarity with apps ○ Apps with overwhelming information would not be used ○ Preference for apps with minimized user input ○ Apps with a price would not be used
<p>Structured Workouts as a Resource</p> <ul style="list-style-type: none"> • Workouts created by exercise professionals would be helpful • Barriers to utilizing structured exercise programs <ul style="list-style-type: none"> ○ Demotivating language ○ Separated from typical exercise culture
<p>Health Professional Support as a Resource</p> <ul style="list-style-type: none"> • Positive experiences with professionals • Negative experiences with professionals <ul style="list-style-type: none"> ○ Preferences for characteristics of professionals
<p>Support Groups as a Resource</p> <ul style="list-style-type: none"> • Value of specific shared experiences • Negative experiences in support groups

Barriers to exercising with T1D

Theme: Frustration due to exercising with non-T1D related concerns

The greatest barrier that kept participants from incorporating regular PA into their lifestyles was a general lack of motivation. Several other contributing factors included extreme thirst and lack of time in the day, as one participant noted *"it's kinda hard to find the time to get moving"* (FG2). Busy schedules and time constraints played heavily into motivational issues as

did dealing with the aftermath of exercising including dehydration, soreness, and exhaustion. All of these barriers to exercise are common in individuals without T1D as well.⁴

Theme: Frustration due to exercising with T1D related concerns

Participants found it frustrating and discouraging when they put effort into attempting to exercise but still had a fear of their blood glucose levels going too low or too high during PA. This deters participants from prioritizing exercise, as one participant noted “*when your blood sugar drops in the middle it’s hard for me to continue the workout*” (FG4). A few participants felt that the exercise might not even be worth completing because this barrier was so prominent or because they would have to consume something after the exercise to correct their blood glucose levels, which “*feels counterproductive to the exercise itself*” (FG2).

Subtheme: Necessity of Planned Workouts with T1D

A common consensus was that T1D makes exercising spontaneously much more difficult. Participants noted having to plan exercise into their schedules, which is already “*really challenging to sort of plan out blood sugar wise*” (FG3) and increases frustration when suboptimal blood glucose levels force participants to alter their exercise schedules. Because this planning can include time-consuming strategies such as eating differently throughout the day, PA is much less likely in this case. Even if participants were committed to incorporating exercise into their schedules, it still “*takes a couple trial rounds to figure out how to keep my blood sugar stable*” (FG4), which creates additional frustrations related to the amount of time this planning takes as well as a fear of trying new exercises.

Subtheme: Unpredictability of Blood Glucose Levels with T1D

Planning exercise can feel futile when participants have little control over external factors that cause unpredictable blood glucose levels. These factors make blood glucose levels so

difficult to predict that participants' reactions are "*unexplainable sometimes it's just so frustrating*" (FG1). This is also why participating in new exercises is so stressful for individuals with T1D, because the unknown ways in which new exercise will affect blood sugar levels is so feared. Participants agreed that even in a routine, blood sugar levels can change unexpectedly as "*you can do exactly the same thing ... and something different will happen*" (FG4). With the unpredictable nature of blood glucose in those with T1D it is difficult to anticipate blood glucose levels during workouts, so participants find they are constantly adjusting their insulin doses before, after, and during exercise to prevent erratic blood sugars. Participants expressed difficulties with finding proper education about this issue because types of exercises affect everyone differently.

Subtheme: Concerns related to overexerting oneself

Many participants, especially from focus group 1, highlighted their tendency to overexert themselves during exercise and their fear of going over their personal limit. One participant noted "*a lot of people misuse the fact that exercises are important for us and some people just overdo it*" (FG1). This may be due to the concern of being unable to distinguish between symptoms of exhaustion and hyperglycemia or hypoglycemia which can all include tachycardia, extreme thirst, and tiredness. This fear can serve as a deterrent to exercise as it can quickly turn into a dangerous situation.

Apps as a Resource

Theme: Apps that gave suggestions would be helpful

Overall, participants across all four focus groups appreciated the idea of an app that gave exercise suggestions and ways to help plan safe exercise sessions as they felt that it was the most accessible resource and would be available all the time. Additionally, an app was the best option

to consolidate a combination of resources in one spot. Participants agreed that this resource would be a great way to take *"the pressure and the mental stuff off of you"* (FG4), which would target a major barrier to exercising regularly with T1D. Having an app that would organize all your data in a concise place would be a *"relatively easy and user-friendly way to encourage diabetics to exercise without it being such a hassle"* (FG3).

Theme: Apps do not support general lifestyle routines

The use of apps as a resource to promote safe exercise habits was conditional. Some participants would not realistically use any of the apps we mentioned because they were already used to working out as a part of a team or did not use a CGM that would be compatible with said app. Participants also feared that any app that gave exercise recommendations might advise a rigid schedule or give too many suggestions that would not fit in to their lifestyles. The possibility of older or younger age groups not using apps because of their unfamiliarity with technology or potential for eye strain was also mentioned.

Subtheme: Unfamiliarity with apps

A major barrier to using these blood glucose tracking apps is that they are not well-known. Only two participants mentioned that they had heard of these apps before our conversation, so there was initially some hesitation and apprehension when thinking about downloading one to use. One participant mentioned that introducing these apps during initial diabetes education would be helpful so patients with T1D can learn the benefits of using apps in glucose level management early on in their experience with T1D.

Subtheme: Apps with overwhelming information would not be used

The possibility of being overwhelmed by too many suggestions from an app was concerning. Because *"diabetes is already a 24/7 thing that never gives up and just feeling like*

I'm having to put extra time and mental energy into diabetes" (FG3) was a strong concern, participants were worried that this extra information would create fatigue or stress instead of ease. The education levels of app users would also have to be considered so that the information the app provides would be presented in a way that was digestible for the specific individual. Participants expressed that there is an overload of information explained at the time of T1D diagnosis and that this information overload continues with participants having to sort through research to find the best routine for them. Without having a way to filter information, participants feel that apps would only complicate their path to finding the right exercise routine.

Subtheme: Preference for apps with minimized user input

Participants noted that they were already used to inputting so much necessary information with T1D such as their carbohydrate counting and insulin dosing, so extra work required for any app might deter participants from using it. This is especially true for app users that are not as well-versed in technology. Because participants felt *"it's easy to be saturated by all of the technology that I have to deal with just to manage my diabetes that I don't necessarily want to add something else" (FG3)*, it was important to participants to have all of these features as automated as possible. Integrating the app with the management apps participants are currently using, such as those for their CGMs, would lower this barrier and be an attractive option as additional support.

Subtheme: Apps with a price would not be used

The use of an app to assist with exercise routines was relatively low on the priority lists of participants when it came to expenses. Multiple participants noted that T1D management was already expensive, and one participant made her priorities clear by stating *"you have to get your insulin before you have to download an app" (FG2)*. However, the idea of a free trial run was

well received by participants, since it would allow users to determine if the app assisted with their PA routines before making a commitment.

Structured Workouts as a Resource

Theme: Workouts created by exercise professionals would be helpful

Some participants enjoyed the idea of having a consistent and personalized exercise routine made for them by a program or personal trainer because it would be *“helpful to get started with something ...new and then you have more information to go off and do it on your own” (FG4)*. Younger individuals or those who are recently diagnosed may especially benefit from this resource because it would eliminate the barrier of not knowing how long to exercise or what specific exercises to do and would relieve some of the mental effort that goes in to preparing for this. One participant even mentioned her success with and appreciation for a coach who gave her specific workouts to do based on her blood glucose levels.

Theme: Barriers to utilizing structured exercise programs

Subtheme: Demotivating Language

Focus group 4 was specifically hesitant to using this resource because they were fearful that the language these resources use would demotivate them. Specifically, GlucoseZone's main claim to help "control your diabetes and lose weight"¹⁶ was not well received because *“it implies that you’re not already in control like you need to do better than you were doing” (FG4)*.

Participants in this focus group reiterated the idea that blood glucose levels are *“not really possible to control it as it is often unpredictable” (FG4)*, so they were fearful that exercise programs from a personal trainer or glucose zone would demand unrealistic results from them.

Subtheme: Separated from typical exercise culture

A barrier to participating in structured exercise programs is that they can isolate participants from exercising with individuals without T1D and would be *"another reminder that ... you're different"* (FG2). It was mentioned that T1D already makes participants feel removed from individuals without T1D throughout the day, so participants would appreciate any way they could be treated like the general population. Additionally, one participant mentioned that she would be even less likely to use this resource because her way of *"coping is almost deidentifying with diabetics"* (FG4).

Health professional support as a resource

Theme: Positive experiences with professionals

A few participants mentioned positive relationships they had experienced with various health professionals. For example, one participant noted that his experience with a dietitian *"reshaped my relationship with food"* (FG3) and another participant felt that *"the help from a lot of different people in different medical fields is going to be very helpful"* (FG1P4).

Theme: Negative experiences with professionals

A few participants had negative experiences with professionals such as endocrinologists or nutritionists in the past because they did not give participants enough autonomy in decision-making. Focus group 4 reiterated the idea that they were fearful of health professionals using judgmental language and a participant from focus group 1 noted that too many different opinions might result in *"too much rush or a clash"* (FG1). Comments from professionals may also feel alienating for patients who then assume they aren't living the "right" kind of life for their disease.

Subtheme: Preferences for characteristics of professionals

A combination of health care professionals who had a background in diabetes care were also reported to be an attractive support option for participants. Each focus group mentioned that

they preferred health professionals with certain characteristics. Whether the health care professional was trained in T1D, was a T1D themselves, came from a unique ethnic background, or trained in certain life stages with T1D, participants appreciated the idea of a health care professional who would know how to deal with a participant's specific situation. Many participants wanted to communicate with a nutritionist, endocrinologist, or certified diabetes educator who was a T1D themselves because *"you can't understand it until you have it and you know what those lows and those highs really feel like"* (FG2). Participants believed this perspective allow professionals to be more open to suggestions from the patient results in more realistic advice. Diversity in professionals also gives participants a more well-rounded pool of professionals to draw specific advice from.

Support Groups as a Resource

Theme: Value of specific shared experiences

Across all focus groups, participants felt that support groups were a useful resource to share stories with individuals who had similar experiences to them as a way to promote a sense of community. One participant mentioned *"finding people who you can talk to, like other diabetics who you can like relate to and get advice from them is incredibly useful. That kind of enabled me to start working out and feel safe doing it"* (FG3). Participants in focus group 1 stated that support groups help them feel less alone in an environment that is not judgmental and is working to *"achieve a common goal"*(FG1). The specificity of these groups plays a large role in whether they are helpful or not. Communicating with *"someone who understands and especially when you can find someone who's in your niche"* (FG4) would help participants filter out some of the judgmental and negative comments that are also present in these groups.

Theme: Negative experiences in support groups

Some participants were wary about the use of support groups because of negative experiences with them in the past that included the spread of misinformation or judgmental comments. Participants felt that *“it feels like a competition when people are talking about their A1cs and you start to just feel a little inadequate”* (FG3). Other opinions were shared that participants *“didn’t really get much out of it”* (FG2) and saw how *“more often than that nothing really happens in them”* (FG2). Choosing how much interaction the users have with support groups might combat these issues.

Cross-cutting Considerations

Although we approached the FG discussions aiming to find the results mentioned above, upon further analysis through an inductive approach we also found the following overarching and cross-cutting themes that presented across all of the topics in our focus group discussions.

Theme: Desire for resources to be tailored specifically to the individual

Because T1D and different exercises affect each individual differently, participants wanted to see resources that were less generalized and more specific to an individual's situation. It was extremely important to have resources tailored to participants' specific experiences (a certain life stage, sport, education level, cultural background, etc.) so this type of support would be easier to understand and use. This idea was mentioned across all resources; whether it was an app that *“provides the specific advice depending on whether your exercise is planned or unplanned”* (FG1), a support group with individuals *“in your niche”* (FG4), or a health or exercise professional giving suggestions based on an individual's lifestyle, participants were *“interested to see how they tailor it for everyone”* (FG2).

Theme: Accessibility of Resources

Many barriers to using all of the resources mentioned in our FGs included their accessibility; education level, age, lack of access to technology, and price were all mentioned as accessibility issues that would prevent individuals with T1D from using these resources.

Participants felt that a consolidation of all resources in one area, such as on a website that could be posted on social media or that endocrinologists or CDEs could provide when patients were initially diagnosed with T1D, would be especially useful to improving the awareness of all of these resources. These advertising techniques were important to spread awareness of all of the resources so they are available to as many T1D patients as possible.

Theme: Resistance to resources due to previous negative experiences

Participants were much less likely to use a resource again if they had any poor experience with it in the past. For example, some participants mentioned that they judgmental comments they had experienced both from professionals and support groups made them stop going to these places for support. Another participant said that a previous experience with a food-tracking app had the potential to “*develop some really potentially dangerous eating habits*” (FG3). These negative experiences caused significant apprehension to the idea of using these resources in the future.

Theme: Fear of using resources that would suggest strict lifestyle changes

Participants felt that they would not listen to recommendations that promoted a strict regimen or provided too many changes to their original routines. Resources that would “*constantly puts me in a box*” (FG4) or “*give me all these like really unrealistic exercises or just like things that wouldn’t work in my schedule*” (FG2) were disliked by participants across all discussion topics. This cross-cutting theme comes from the idea that participants did not want to feel separated from other individuals without T1D, would not consider recommendations from

professionals or support groups exactly as they were given, and were hesitant to accept overwhelming information from resources.

Theme: Miscellaneous and Self-Prompted Resources

Participants mentioned a variety of resources other than the four that were asked about from our focus group script. FG 1 mentioned that *"determination in self"* and *"learning your body"* were the most important factors in exercising safely. This highlights the need for more mental health resources targeted specifically to individuals with T1D. A few participants in FG 2 could not speak highly enough about their Dexcoms, noting that a Dexcom is the *"number 1 tool that keeps me sane and exercising safely"*. FG 4 also realized the importance of self-confidence while exercising, stating that *"I have to be forgiving of my mistakes because I'm gonna make a lot of them"*. FG 3 brought up an interesting point of using exercise as a resource itself to help control their blood glucose levels because a few individuals had experience in the past with going on a walk to lower their blood glucose levels.

Discussion

Participants enjoyed the idea of using the resources we mentioned to assist with their exercise routines, but many barriers and conditions to resource utilization were mentioned.

Reactivity to resources

There was a varying length and depth of discussion about each prompted resource. Participants had the most to say about apps, which might be due to the fact that this resource was the first one mentioned in the FGs or the idea that participants were most likely to use this resource out of all the others mentioned. Apps were considered to be the most accessible resource, yet only two participants mentioned that they had used such apps before. Participants were less likely to use professional help and support groups due to previous negative

experiences, and there was little enthusiasm and the least amount of quotations across all focus groups for structured workouts as a resource. This may be attributed to participants' need for a trial run or more information to determine the usefulness of these resources and whether they would actually fit into participants' schedules. Overall, participants were eager to continue using the self-prompted resources that they already had success using such as their Dexcoms and CDEs.

The ideal resource

Based on the combination of discussions we had and overarching themes we found, participants felt that the ideal resource would be personalized and specific to user's lifestyle, have a combination of resources in one place, require as little user input as possible, give the participant autonomy in making decisions, and provide flexible suggestions. These characteristics of resources to assist in exercising with T1D are consistent with the "smart" calculators or learning technology that is recommended in the literature, considering that in order to have all of these qualities a resource must be able to adjust to a participant's blood sugar level changes as frequently as they occur.⁶ The overall sentiments of participants suggested that they would also probably use these resources to assist with more than just their exercise routines, as they found that other aspects of T1D in their lives would be improved with these resources too.

Further considerations/In reality...

The first comments offered about each prompted resource were typically always positive, but eventually transitioned into barriers to using these resources as participants considered the realistic potential of actually utilizing them. Overall, participants expressed that their hopes for ideally managing blood glucose levels during exercise are low since they have faced so much frustration and failure with this issue in the past. The question is, then, whether or not the

“perfect” resource would actually be able to ideally manage blood glucose levels during exercise for the diversity of experiences among those with T1D, which is evidenced by the observation that there were more subthemes and quotations present in our data about barriers to utilizing resources rather than reasons for using them. This sentiment raises the need for targeted education about these resources or earlier intervention at the time of diagnosis so that the individual with T1D does not have to navigate exercising on their own and experience these barriers to exercise without the support of resources to diminish them.

Differences in FG 1 (100% AA Participants)

Although unintentional, FG 1 was comprised of only participants who identified as Black or African American. Some differences existed between this focus group and the following three focus groups, which consisted of a majority of participants who identified as white. For example, FG 1 held a shorter discussion about barriers to resources and overall were more supportive of the idea of using resources with their exercise routines compared to the perspectives of other focus groups. The participants in FG 1 also provided more general opinions and fewer reasons to support their statements. Compared to other focus groups, more participants in FG 1 were concerned about overexerting themselves, reliant on self-belief and personal determination as a resource to assist with their exercise routines, and enthusiastic about the importance of exercising with T1D. Additionally, FG 1 participants provided more of their participation through the chat option on Zoom as compared to stating their perspectives out loud.

We cannot assume the reasons why these differences between FG 1 and all other three focus groups occurred, as this project was not designed to do so, but we provide some suggestions to contextualize these differences. Firstly, the quotation material and frequency could be due to researcher error, as this was our first FG discussion in this project. As the

discussions progressed, the researcher became more familiar and comfortable with the FG script and process, which in turn could lead to a greater feeling of ease among the participants to share more of their perspectives. African American individuals may also have a different familiarity or experience with the research process as shown in the literature, which could have contributed to the types of quotations they provided and how they did so (in the chat).²⁰ These individuals in FG 1 may have had a different experience with T1D compared to participants in other FGs, as evidenced by their reports that 100% of FG 1 participants used multiple daily insulin injections with 75% who routinely used a CGM compared to majority of the participants in other FGs who used insulin pumps instead of multiple daily insulin injections.

Limitations:

There were several limitations to this study due to timelines and recruitment strategies. Although the second aim of this project intended to split participants into two even groups of those who met the ADA recommendation for PA in the previous week and those who did not, we were unable to recruit enough participants who reported that they participated in at least 150 minutes of moderate to vigorous PA in the previous week. This error was also due to the need to balance participant schedules at the time of recruitment with their reports of PA. However, this recruitment observation is consistent with the literature that majority of individuals with T1D do not incorporate enough PA into their daily routines.¹ We also found recall bias in participants' reports of how often they exercised in the previous week, as they would state a certain routine in the eligibility survey but then report more or less exercise in the focus group discussions. The use of one research member as a recruitment contact, FG script author, sole FG moderator, transcript scribe, and data analyst, though necessary due to timeline constraints, may also result

in some bias in the FG discussion and analysis and therefore can compromise some of the credibility of the themes we collected.

Our sample size and characteristics also revealed some limitations to this study. Firstly, the majority of participants were non-Hispanic white (65.5%) and female (65.5%). Participants were, on average, on the younger side of the young adult range (about 25 years old within 18-40 range). The fact that focus group discussions were held on zoom contributes to the limitations of conducting qualitative research online and the necessary characteristic of participants to have access to technology in order to participate.²¹ The literature has shown that conducting qualitative research through Zoom may slightly compromise the research process due to possible technological issues, lack of face-to-face contact, and a feeling of detachment from the conversation.²¹ Additionally, participants in previous studies have expressed difficulties in establishing a rapport with a group virtually, which could create biases in the perspectives that are shared and the consensus that is reached in the group.²² Majority of participants (75.9%) reported that they had used resources to assist with their exercise routines before. Each of these limitations suggests that our participants may have been more familiar with the use of technology and resources compared to the general T1D population, including individuals who we were not able to recruit with no access to technology or lower education levels as well as those who had just recently been diagnosed with T1D. These individuals might face additional barriers to exercising with T1D that resources would need to be targeted in future efforts.

Conclusion

Resources can assist in the safety and frequency of exercise routines among individuals by providing safe suggestions and a supportive environment.¹⁷ We propose a variety of resources to encourage PA for people with T1D including apps to track blood glucose level patterns,

exercise programs created specifically for those with T1D, support groups, and support from health professionals to diminish the barriers that keep individuals with T1D from incorporating sufficient PA into their lifestyles. It is necessary to investigate the desires and concerns of those with T1D who would be using such tools to identify which kinds of support they are looking for in their exercise routines in order to aid in the development of ideal resources and the implementation of proper guidance and education.

Participants appreciated the resources we mentioned yet would not practically use them unless the resources were accessible, specifically tailored to an individual's situation, and unlike previous negative experiences with resources. The perspectives we collected suggest that barriers to exercising with T1D and the qualities of ideal resources to combat them are largely consistent with the existing literature,^{3,4,5,6} but more research needs to be conducted regarding the realistic potential and personalization of resources. Further studies could also target a wider variety of resources such as health policy interventions, access to gyms or green spaces, and team sports participation or dive deeper into specific resources to identify certain features that would increase user satisfaction. Participants noted many barriers to using such resources that varied depending on their previous life experiences with T1D. This raises the need for user support regarding such resources at the time of diagnosis to limit preventable barriers that arise from navigating exercise on one's own without the appropriate amount and specificity of support. Providing these resources at the beginning of an individual's timeline with T1D can both increase the likelihood of their continued participation in exercise and improve their quality of life with the disease.

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Concluding Thoughts

My hope for this project was to learn how to ease the lives of individuals living with T1D when it comes to exercising, but I learned there is no one-size-fits all answer that could easily diminish the barriers to exercising with T1D. Instead, we found the characteristics of resources that participants liked and disliked, which can be used in the initial development stages of these tools to maximize user satisfaction. For example, the appeal of resources that are personalized, offer flexible suggestions, and have automated features should be accounted for in the future resource design. I enjoyed listening to the perspectives and stories of participants and learned of the importance of qualitative research in that it is not only more personable and easier to understand for all education levels compared to quantitative research but that it also uniquely analyzes the desires and concerns of participants to transform them into useful interventions and transformations.

This study is the first of my knowledge that proposes a variety of resources as a method of action to decrease the barriers present to exercising with T1D. Further studies should aim to understand if resources with the qualities that participants desired can realistically be created and implemented. Future research should also target a wider variety of resources and participants who may not be as familiar with the utilization of technology and resources to assist in exercise routines in order to account for the greater T1D population. This project raises the need for the spread of awareness of these resources and the barriers to exercising with T1D, as all participants expressed frustration with the process of exercising. Our results suggest that resources with certain ideal qualities would be a promising intervention in increasing the number of individuals with T1D who incorporate PA into a healthy lifestyle.

Appendix

Electronic Questionnaire Survey Questions

We are aiming to discover how to best assist young adult T1D patients with their exercise routines by understanding the most useful resources to diminish the barriers T1D patients face while exercising, which will inform future educational tools for those with T1D who are beginning to regularly exercise. You are being asked to complete this questionnaire to determine if you are eligible to participate in this study, as participation is completely voluntary. We do not anticipate any risks associated with this study, but if you have any questions or concerns please contact the study coordinator Carly Medwin at cjule@live.unc.edu. You may also call or email the UNC Institutional Review Board at 919-966-3113 or irb_subjects@unc.edu.

If you are eligible to participate in this study, you will be contacted by the research team to schedule a date and time for the focus group discussion. If you are not eligible to participate in this study, we appreciate your interest and time but we will not ask for anything else from you.

- 1) What is your date of birth?
 - a. Short answer/date box
 - b. If you're under 18, thank you so much for your interest in our study!!
Unfortunately, you are not eligible to participate. Please be on the lookout for other similar studies in the future!!
 - c. If you're over 40, thank you so much for your interest in our study!!
Unfortunately, you are not eligible to participate. Please be on the lookout for other similar studies in the future!!
 - d. 18 through 40 – next question
- 2) Which of the following do you best identify with?
 - a. Female, Male, Non-Binary, Other (short answer), Prefer not to answer
- 3) Which of the following best describes you?
 - a. Select all that apply: Asian or Pacific Islander, Black or African American, Hispanic or Latinx, Native American or Alaskan Native, Non-hispanic White, Other (short answer), Prefer not to answer
- 4) What year were you diagnosed with Type 1 Diabetes?
 - a. Within 1 year – Thank you so much for your interest in our study!! Unfortunately, you are not eligible to participate. Please be on the lookout for other similar studies in the future!!
 - b. 1 year through >10 years – next question
- 5) Do you use multiple daily insulin injections or an insulin pump?
 - a. Multiple daily insulin injections, insulin pump, other
- 6) Do you use a continuous glucose monitoring device?
 - a. Never, routinely, occasionally

Please answer the following questions based on your typical exercise activity over the past 7 days, even if you do not consider yourself to be a very active person. Please include the activities you do at work, for leisure, for house or yard work, and for travel.¹

- 7) Within the last 7 days, how many days did you do vigorous activities including weight lifting, running, aerobics, or sports for at least 10 minutes at a time?¹

- a. 1 through 7 days -> How much time did you usually spend doing vigorous physical activities on one of these days?
 - i. Hours & minutes (short answer)
 - ii. Unknown
- 8) Within the last 7 days, how many days did you do moderate activities including casual bicycling, dancing, or yard games for at least 10 minutes at a time?¹
 - a. 1 through 7 days -> How much time did you usually spend doing moderate physical activities on one of these days?
 - i. Hours & minutes (short answer)
 - ii. Unknown
- 9) Within the last 7 days, how many days did you walk for at least 10 minutes at a time?¹
 - a. 1 through 7 days -> How much time did you usually spend walking on one of these days?
 - i. Hours & minutes (short answer)
 - ii. Unknown
- 10) Have you previously used any resources to assist in your exercise routine? If so, please list them below. These could include apps, trainers, groups, or any other items or services that have made your physical activity routine easier.
 - a. Short answer
 - b. N/A
- 11) Compared to your typical amount of physical activity, would you like to exercise:
 - a. About the same amount
 - b. More
 - c. Less
- 12) What is your full name?
 - a. Short answer
- 13) Please leave your preferred mode of contact (email address or phone number) below. Thank you for completing our survey! Have a great day!
 - a. Short answer

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Type 1 Diabetes Exercise Resources Focus Group Guide

Introduction: Hi there!! Thank you so much for taking the time to offer your thoughts as we work towards reducing the barriers to exercising with Type 1 Diabetes (T1D). We are conducting this focus group on behalf of the Mayer-Davis research group at UNC Chapel Hill.

A focus group is a small discussion that aims to gain unique perspectives as well as a group consensus about a particular topic. Your participation and comments in this focus group are completely voluntary, and you are not required to answer any of the questions.

Purpose:

- To discover how to most effectively assist young adults with T1D with their exercise routines through the use of supportive resources. Based on our previous research, we are aware that concerns about blood sugar can make exercise challenging for people with T1D. Ideally, resources such as these could help to assure safety in exercise routines and inform future educational tools for those with T1D who are beginning to regularly exercise.
- We're hoping for your feedback on resources we suggest as well as personal experiences with anything you've used to help you exercise in the past. Please feel free to add anything to the discussion that you find relevant!

Agenda:

- Start with a review of consent
- Discussion of barriers to exercising with Type 1 Diabetes
- Discussion of currently available resources, ideas for future resources, and personal experiences you've had with resources regarding exercise assistance

Informed Consent: We want to be sure that you are completely aware of what your participation in this focus group includes. You should know the risks and benefits to contributing in this focus group and decide whether to participate.

- This focus group will take up to 1.5 hours of your time
- There are no direct benefits to you, but you may gain knowledge from other perspectives in the focus group
- You will also be mailed a \$25 Visa gift card to thank you for your time and effort in participating in this study.
- We do not anticipate any risks, but you may experience a loss of anonymity if other participants disclose information you share. We ask all participants to respect the confidentiality of other participants and to not repeat anything shared outside of the discussion today. The researchers will not reveal your names or any distinguishing characteristics in the analysis of this study.
- For analysis purposes, we would like to record only the audio of this focus group so that we can transcribe everything that was said. Once the transcript is created, we will destroy the audio recording.
 - Only research members present in this focus group today will have access to the transcript and audio recording, as they will be locked from all other access.
 - The transcript will also be erased once we have used it to determine the main themes of today's discussion.
 - Your name will not be included in the transcript.
- You are not required to share any personal medical information.
- Your participation is completely voluntary, as you are not required to answer any of the questions and can stop participating at any time in the discussion.
- If you have any further questions, you can privately contact any of the research team members, Dr. Beth Mayer-Davis (who is the principal investigator of this study), or the UNC Chapel Hill Institutional Review Board.

Start recording and inform participants that they can choose to turn their video off or change names whenever they would like.

If you are not familiar with the focus group process, here is an overview:

- The research team members will prompt the discussion with questions we are aiming to answer about barriers to exercising safely with Type 1 Diabetes and resources that might help diminish these barriers.
- You are welcome to share anything you would like about your thoughts related to these questions, or you can bring up new questions or ideas that we have not asked about.
- Everyone will have a chance to discuss what they like or dislike about each question or topic. You can raise your hand or just unmute yourself.
- We are welcome to agreements and disagreements, but we ask that everyone maintain a respectful manner towards the conversation and other participants' viewpoints.
- You can share more for certain topics and less for others. You do not have to respond to every question, but you are definitely welcome to do so.

Questions for both focus groups:

1. Does anyone want to share an exercise that they like to do over Thanksgiving?
2. Do you find anything challenging about exercising in general – not necessarily related to Type 1 Diabetes?
3. Do you find anything challenging about exercising with Type 1 Diabetes specifically?
4. Generally, what actions could resources do to target these challenges? These could be resources to assist you physically or mentally.
5. Let's start the discussion about resources with apps tailored specifically to exercising with Type 1 Diabetes.
 - a. Do you think apps such as T1Exercise, DiaBits, Glucose Buddy, One Drop, and mySugr are useful in supporting safe exercise habits with Type 1 Diabetes?¹
 - i. Provide explanations of apps if necessary¹
 - b. The Mayer-Davis lab is currently in the process of creating a mobile-health tool that aims to combine user data (from CGMs or other devices), exercise guidelines, and eating habits to provide real-time strategies for exercise suggestions. Do you think this would be useful in supporting safe exercise habits for people with Type 1 Diabetes? Why or why not?
 - i. Provide explanation if necessary²
6. How about exercise programs and workout plans tailored specifically to individuals with Type 1 Diabetes? Glucose Zone (provide explanation if necessary³) and personal trainers are both examples of these. Do you think this would be useful in supporting safe exercise habits for people with Type 1 Diabetes? Why or why not?

- a. Would you find the combination of support from a nutritionist, physical therapist, or endocrinologist to be useful with this resource?
7. What about joining a support group (virtual/social media or in person) with other individuals with T1D who are continuing on their fitness journey? Do you think this type of comradery would be useful in supporting safe exercise habits for people with Type 1 Diabetes? Why or why not?
8. Do you have any suggestions for or experiences with other resources that might be useful in supporting safe exercise habits for people with Type 1 Diabetes?
9. Do you have any suggestions for or experiences with other resources that might be useful in supporting more frequent exercise habits overall? These resources may not be related to Type 1 Diabetes at all.
10. Let's discuss the feasibility of these resources. How do aspects like price, time, education, technology access, user-friendliness, or environment contribute to the probability that you would actually use these resources?
11. Can you think of any barriers to using these resources?
12. Is there anything else you'd like to share with us?

Questions specific to focus group with frequently exercising participants:

13. Do you have any advice or tips for individuals with Type 1 Diabetes who are just starting on their fitness journey?
14. What did you find to be the most useful when you were starting out on your fitness journey?

Conclusion: Thank you so much for your input and perspectives on these questions! This discussion was very helpful and your comments will not only be useful in creating safe and effective exercise habits, but also in easing the lives of those with Type 1 Diabetes overall. Please be on the lookout for an email from us regarding the shipment of your Visa gift card very soon. Thank you again, and have a great day!!

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