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# Outcome measures for physical activity interventions in children with Type 1 Diabetes

## A Systematic Literature Review

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# ABSTRACT

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This study examines physical activity intervention outcome measures in children with Type 1 Diabetes (T1D). Additionally, it explores medical and psychosocial outcomes. Five databases (CINAHL, PsycINFO, MEDLINE, PubMed, Scopus) were used in this study. The selection of articles was done by using exclusion and inclusion criteria. The articles chosen for this study were restricted to those written in English and had to be peer-reviewed and published between 2012 and 2023. Besides, the focus was on quantitative studies. Six articles were eligible to be used in this study. Intervention types, durations, and outcome measurements have been reported. Results showed that the length of intervention should be more than twelve weeks to see the actual effect of interventions.

Additionally, while an effect of physical activity on glycemic control was observed, generalizable psychosocial outcomes could not be obtained. In future research, to reach generalizable conclusions, the sample of this study should be expanded. Also, in addition to clinical data, getting psychosocial data can provide helpful insights. It can offer tips to improve participants' quality of life.

Keywords: Type 1 Diabetes, Self- management, Physical activity, Glycemic control

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# 1 Introduction

Engaging in regular physical activity (PA) has numerous positive effects on the physical and mental well-being of individuals living with Type 1 Diabetes (T1D). These advantages are highlighted in the current clinical guidelines (Mitchell et al., 2017). It is common for individuals with T1D to fall short of the recommended daily amount of PA, which entails 60 minutes of moderate to vigorous activity. This lack of activity can lead to lower levels of physical engagement compared to peers without diabetes. Additionally, adopting sedentary behaviors, such as prolonged sitting or lying down while awake, can negatively affect health (MacMillan et al., 2016). Young people are progressively dedicating more time to watching television and using computers. Various studies point to a concerning link between sedentary behaviors like watching TV and the development of obesity in children (Galler et al., 2011). Moreover, evidence in the research of MacMillan et al. (2014) supports previous information. Exercise is a fundamental component in managing Type 1 Diabetes (T1D). Its benefits encompass aiding in glycemic control, diminishing the risk of cardiovascular diseases, and enhancing overall quality of life (Alazmi et al., 2022; Vartak et al., 2021). On the other hand, it is noteworthy that many T1D patients harbor apprehensions regarding exercise due to the potential risk of experiencing hypoglycemia. This concern revolves around navigating how to adjust insulin doses and carbohydrate intake to limit disruptions in glycemic control (Vartak et al., 2021). Diabetes creates challenges in daily life, and keeping an eye on blood sugar levels is crucial for maintaining good metabolic balance. The combination of physiological and psychological shifts during adolescence can lead to a decline in metabolic regulation, and diabetes adds an extra load to an already difficult phase of life (Lorentsen & Bergstad, 2005).

# 2 Background

## 2.1 Type 1 Diabetes

Constituting 5-10% of diabetes cases arises from the destruction of pancreatic beta cells. This is also referred to as "insulin-dependent diabetes" (American Diabetes Association; 2. Classification and Diagnosis of Diabetes, 2018). T1D (Type 1 Diabetes) patients always need good insulin replacement management. Furthermore, patients need extra attention on their meals (Levy, 2011).

### 2.1.1 T1D and Glycemic Control

Glycemic control includes Hb1Ac (blood sugar) level and daily insulin dose. The blood sugar level is usually unstable, but glycemic control management is vital to prevent hypoglycemia and hyperglycemia (Levy, 2011; Galassetti & Riddell, 2013). Not taking care of the illness properly and not keeping the blood sugar levels in control can cause big problems. These problems can be both short-term and long-term and can affect quality of life (Alazmi et al., 2022).

### 2.1.2 T1D and Body Mass Index

Even if the illness is well taken care of, kids with Type 1 diabetes often end up with a higher body mass index (BMI) compared to those who do not have diabetes (Alazmi et al., 2022; Ostman et al., 2017). This is particularly important because childhood obesity is becoming more common worldwide. Even without diabetes, there are many overweight kids, and the country also has one of the highest rates of Type 1 diabetes globally (Alazmi et al., 2022).

## 2.2 Self-Management Model

This model is part of the Bandura's social cognitive theory. In the discussion part results will be discussed based on this theoretical approach. Changing health habits is not just about wanting to change. It needs motivation and the ability to control yourself. Taking care of yourself involves different ways of thinking in your mind (Bandura, 2004). People have to learn how to watch their health behaviors, the situations that make them act a certain way, and how to encourage and guide themselves to do better. They also need to know how to reward themselves and get help from friends and family to keep going (Bandura, 2004). When dealing with ongoing sickness, it is important to learn how to manage your health over time. The idea of managing yourself is liked by many because it is made to fit each person's needs. It gives them personal advice that keeps changing as they do. This kind of help does not need a special place or a lot of people. It is a mix of personal help and ideas that can help lots of people (Bandura, 2004). By using the internet, this self-management idea can reach more people, no matter where they are or when they want to use it (Bandura, 2004).

# 3 Rationale

For young people with Type 1 diabetes, it is important to be active and do physical activities regularly. They also were supposed to adjust their insulin and food as needed. The recommendation of governments suggested that kids and teenagers should try to do around 60 minutes of moderate to strong physical activities each day (Quirk et al., 2014). Being active like this had lots of beneficial effects on their health. It helps their heart and body stay healthy, keeps their weight in check, makes their bones stronger, boosts their self-confidence, and helps them to socialize (Quirk et al., 2014). Although being active has benefits for mental health, most of the studies have not looked at how it affects those with Type 1 diabetes (Quirk et al., 2014). In addition to encouraging children to keep active, it was important to maintain an active life (Quirk et al., 2014). When considering the impact of physical activity intervention on children/adolescents with T1D, it is a matter of curiosity whether the effects on their psychological well-being are being addressed, and how the biological challenges experienced in the body affect them.

# 4 Aim and Research Question

## 4.1 Aim

This literature review aims to explore the outcome measures used for physical activity intervention for children with type 1 diabetes. At the same time, it aimed to examine the clinical, behavioral, and psychological outcomes of the synthesized articles.

## 4.2 Research Questions

1. What are the outcomes of physical activity interventions for children with type 1 diabetes?
2. Do different physical activity interventions have different outcome measures?

# 5 Method

## 5.1 Design

The purpose of a systematic literature review is to answer a specific research question by collecting information from different sources without the need for a new study (Jesson et al., 2011). In addition, a systematic review is a method to review a specific question within the inclusion and exclusion criteria. To allows future replication, the process must be objective and

transparent (Jesson et al., 2011). According to the purpose of the study, a systematic review was preferred instead of scoping.

## 5.2 Search strategy

The database search for this study took place in January 2023. The used databases were CINAHL, MEDLINE, PsycInfo, PubMed, and Scopus. These databases were selected based on the field of research they cover relevant for the study e.g., medicine, health, and social sciences. Similar free search terms were used for all databases. Search terms were determined according to PICO (See Table 1). An example of search terms was "Type 1 diabetes OR T1D OR Type 1 diabetes mellitus AND physical activity OR exercise OR fitness OR physical exercise OR sport OR walking OR cycling AND children OR kids OR youth OR child AND intervention". Different combinations were used depending on the characteristics of each database. For the final search strings See Appendix A.

To meet inclusion criteria articles must been published between 2012-2023, written in English, and peer reviewed. At the end of the research, a totally of 436 articles were found. The procedure's details have shown in Appendix B.

In addition, the reference list of included articles and other systematic reviews was investigated to include other articles; and 5 additional articles were found. These articles are presented in Appendix B as grey literature.

**Table 1**

*PICO*

| PICO | Description |
|---|---|
| ***Population*** | Children and youth with Type 1 diabetes |
| ***Intervention*** | Physical activity, exercise, internet-based physical activities, online intervention program |
| ***Comparison*** | Control group/None |
| ***Outcome*** | All available outcomes |

## 5.3 Selection criteria

Exclusion and inclusion criteria should be determined while searching for articles suitable for the aim of the research question. Before identifying exclusion and inclusion criteria, a preliminary search must be done. In other words, first, the main articles on the subject are scanned and then the criteria are defined. And at the end of the process to be transparent, these criteria are shown to the reader (Jesson et al., 2011). The inclusion and exclusion criteria were created according to the research questions and aim. Also, these criteria were adjusted according to the PICO. (See Table 1 and 2).

**Table 2**

*Inclusion and exclusion criteria*

| **Inclusion criteria** | **Exclusion criteria** |
|---|---|
| ***Publication type*** | |
| Peer reviewed articles<br>Language: English<br>Published date: 2012-2023<br>Full text available | Systematic review articles, books |
| ***Design*** | |
| Quantitative methos, control group, and mixed methods | Unclear method |
| ***Population*** | |
| Children or youths with Type 1 Diabetes<br>Age range: 6-18 years | Type 2 diabetes, children at risks of the Type 1 diabetes, adults, parents, etc. |
| ***Intervention*** | |
| Physical activities (all indoor and outdoor sports), online interventions | Education programs |
| ***Outcome*** | |
| All available outcomes | |

### 5.3.1 Title screening

After a search of all databases, 436 articles were found and 16 of them were duplicates. The first screening process was conducted on the title level after removing the duplicates. The researcher used exclusion and inclusion criteria to determine whether the articles are useful or not. The reason some articles were excluded was that the articles did not meet the inclusion criteria, e.g., systemic reviews, type 2 diabetes, or research with adults were excluded.

### 5.3.2 Abstract screening

After 425 articles were scanned at the title level, 35 articles remained to be scanned at an abstract level. Articles were analyzed considering the inclusion criteria. And, as a result, articles with inappropriate participant characteristics (n=4), systematic reviews (n=8), and inappropriate intervention types (n=4) were not included in this study. After completing this process, 19 articles were left for the full-text screening.

### 5.3.3 Full-text screening

After the title and abstract scanning, 19 articles remained. Articles were scanned within the specified criteria and 6 articles were selected to be used in the research. The criteria are shown in the diagram (Appendix B).

## 5.4 Quality assessment

The Effective Public Health Practice Project (EPHPP) quality assessment tool for quantitative studies was used during assessing the quality of the included studies (Effective Public Health Practice Project [EPHPP], 2019). EPHPP tool is appropriate for assessing multi-program study designs (Deeks et al., 2003). The assessment tool can be used in systematic reviews and the validity of the tool has been determined (Jakson et al., 2005; Deeks et al., 2003). The EPHPP tool rates all studies according to six program aspects, including selection bias, study design, control of confounders, blinding, data collection methods, and withdrawal and dropout rates. Each feature is rated weak, moderate, or strong, and an overall rating is applied to each study (Hurley et al., 2019). Inter-reliability scores could not be calculated since this study has only one author.

The quality of the included studies is shown below (see Appendix D). MacMillan et al. (2014) rated it as "weak". Although it is a quantitative and clinical study, it does not include a specific intervention program. It was not excluded from the study because it contributed to the results of the study.

## 5.5 Data extraction

Considering the aim of the study, article data were obtained with the help of the protocol created by the author in order to answer the research questions (See Appendix C). Important data obtained from the articles were categorized under main headings such as author names, title and publication year, journal, study design, ethical procedures, recruitment method, settings, intervention, and outcome. The ethical part of the research was carefully examined, and the information obtained was added to the file. The 6 selected articles were scanned in detail with sub-titles and questions. In the articles, attention was paid to the 'intervention' and 'outcome' parts.

Data extraction was done with the help of a Microsoft Excel program. The complete Excel file with all the information is available from the author on request.

## 5.6 Data analysis

Data analysis was performed on six articles. First of all, the types of physical activity used in the articles were examined. Similarities and differences were determined according to the frequency and types of interventions. And then, which outcome measurements were used, it was noted that despite the slight differences, similar measurements were used in almost all articles. After the analysis, repetitive and differentiated data were synthesized and categorized (Xiao & Watson, 2019).

As a result, after examining the positive and negative effects of the interventions, which outcome measures were used in the studies were investigated. And considering this information, the author tried to find answers to two basic questions of the research.

## 5.7 Ethical consideration

Ethical considerations are not mentioned because reviewers do not collect data directly from participants. Even though the reviewer does not collect data, it is important to explain correctly every ethical issue, bias, and reported findings in the articles they have use. Also, the reviewer should be objective when relaying the information (Suri, 2020).

All the articles used carried out their studies by ethical procedures. All articles have explanations about the applied procedures. The ethical sections in the articles were examined

with the EPHPP protocol. In this literature review, the data taken from the articles were analyzed correctly and transferred without interfering with the data.

# 6 Results

## 6.1 Overview of Included Articles

Information on the included articles is shown in Table 3. Article numbers in Table 3 will be used as references in the remaining section of this interview. All included articles used quantitative methods. One article did not use an intervention group in the research (2). Two articles used self-reported data during collecting data from the participants (2,5). Four of the articles were rated as having strong quality (1,3,4,6). One of the articles was rated as having moderate quality (5) and one of the articles was rated as having a weak quality (2). There were no excluded articles because of the quality level.

**Table 3**

*Characteristics of included articles*

| *i* | Author | Year | Target Population | Methodology |
|---|---|---|---|---|
| 1 | Tunar et al. | 2012 | Children who diagnosed with the Type 1 Diabetes | RCT |
| 2 | MacMillan et al. | 2014 | Children who diagnosed with the Type 1 Diabetes | CCT |
| 3 | Tomar et al. | 2014 | Children who diagnosed with the Type 1 Diabetes | RCT |
| 4 | Petschnig et al. | 2020 | Children who diagnosed with the Type 1 Diabetes | RCT |
| 5 | Ash et al. | 2019 | Children who diagnosed with the Type 1 Diabetes | COHORT |
| 6 | Hashem Mohammed et al. | 2021 | Children who diagnosed with the Type 1 Diabetes | RCT |

## 6.2 Interventions and Outcome Measures

### 6.2.1 Description of Physical Activity Interventions

Firstly, one of the articles do not include intervention in the research (2). This article measured difference between children who had physical activity and sedentary behavior. The research did not include intervention, but they had measured participants daily movements (2).

All the articles had different type of physical activities (see Table 4). One article had intervention for 32 weeks (4). And article number 5 had follow-up measurements after

interventions. All articles had different frequency and detail of frequency of sessions are shown in Table 4.

**Table 4**

*Characteristics of interventions*

| | Type of physical activity | Duration | Frequency | Interventions other than physical activity |
|---|---|---|---|---|
| **1** | *Mat based Pilates training | 12 weeks | 3 days/week<br>Each session was 45 minutes | Short-acting insulin or oral carbohydrate given if needed |
| **2** | - | - | - | - |
| **3** | *Ten min. warming up and ten min. cooling down.<br>*Walking on a treadmill and a bicycle ergometer | 12 weeks | 3 days/week<br>No more than two days gap between sessions<br>First session started with 50 min. and last session ended with 60 min. | There was no other intervention. |
| **4** | *6 min. run/walk, physical fitness (strength training) | 32 weeks | Twice a week<br>Each session lasted 50 min. and includes 10 min. warming up and cooling down sessions. | There was no other intervention. |
| **5** | * Moderate-to-vigorous intensity physical activity (MVPA) | 12 weeks, 3-months follow up, 7-months follow up | One session/week<br>35 min. of MVPA | After MVPA sessions, participants had 45 min. of discussion of relevant topics. |
| **6** | *Football | 12 weeks | Twice a week<br>1.5 hours | Diet program for Football-diet group and Diet group. |

There was more intervention rather than physical activity intervention in three articles (1,5,6). In article number 1 they applied short-acting insulin or oral carbohydrate given in the case of hypoglycemia or before participants had it. And then article number 6 applied diet

program in two groups as an intervention. Lastly, article number 5 after physical activity intervention they had discussion session and talking about feasibility of interventions and T1D.

### 6.2.2 Outcome Measurements

All the research had different and similar measurement tools to determine the effect of intervention by comparing pre-and post-measures. One of the included articles had follow-up measures (5). Article number 2 used accelerometer to collect the daily data from participants. Table 5 shows the most important outcome measurements for this literature review.

**Table 5**

*Outcome Measures*

| Measurement | Ref. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| **HbA1c** (Hemoglobin) | | ☑ | ☑ | ☑ | ☑ | ☑ | ☑ |
| **BMI** (Body Mass Index) | | ☑ | ☑ | ☑ | ☑ | ☑ | |
| **Daily Insulin Dose** | | ☑ | ☑ | ☑ | | | ☑ |
| **Psychosocial Surveys** | | | | | | ☑ | |

*HbA1c* measurement had been used in all included articles. Also, the articles recorded values of *HbA1c* before and after intervention (1,2,3,4,5,6). Except article number 6 the included had measured *BMI* before and after intervention. Article number 6 measured *BMI* at the beginning of the research and then the researcher measured *BMI* weekly to determine the right diet for participants. However, values for *BMI* did not exist in the article. Some of the articles did not mention the *daily insulin dose* for participants (4,5). Article number 2 recorded the number of injections and pumps. Article number 3 and 6 were recorded before and after the *daily insulin dose* for the participants. *Psychosocial surveys* were used in article number 5. These surveys were Peds Quality of Life, Diabetes Module; Hypoglycemia Fear Survey, Worry Subscale; Self-Care Inventory; Self-Perception Profile, Social Acceptance Subscale.

### 6.2.3 Participants

All participants were diagnosed with Type 1 diabetes. Article 2 collected data from same participants as were mentioned before in the description of interventions part. Participants had different gender, age, and physical activities. Also, article 5 collected data from same sample with follow-up measures. In addition, article 5 supposed to be excluded because of the age

range according to inclusion criteria. However, this situation was ignored because the contribution of the article to this research was essential and there was not significant age difference to affect the results of this study results. All details of groups have shown in Table 6.

**Table 6**

*Characteristics of participants*

| Reference | Number of participants | | | | Age range |
|---|---|---|---|---|---|
| | Intervention Group | Control Group | Drop-out | Total | |
| 1 | 17 | 14 | - | 31 | 12-17 y |
| 2 | 40 | - | - | 40 | 7-14 y |
| 3 | 12 | 12 | 2 | 22 | 12-16 y |
| 4 | 15 | 14 | 8 | 21 | 8-12 y |
| 5 | 18 | - | - | 18 | 11-19 y |
| 6 | 30 | 10 | - | 40 | 12-18 y |

## 6.3 Outcomes of the Physical Activity interventions

Three articles found that intervention had no significant effect on glycemic control (HbA1c, Daily insulin dose) (1,2,3). However, after the intervention, the insulin dose was reduced in the exercise group (3). On the other hand, some of the articles showed improvement in glycemic control (4,5,6). Article 1 mentioned the duration of the intervention. The research argued that glycemic control could improve after 12 weeks. Article 4 results showed that glycemic control improved after 32 weeks of training. These results support article 1. There was improvement in HbA1c level after three- and seven-months follow-up assessments and all participants had self-correcting their glucose level before-during-after intervention (5). HbA1c had improved in football-diet group but not in other groups such as diet group or football group (6).

**Table 7**

*Pre and post intervention effect of included articles*

| | Number of articles | | | | | |
|---|---|---|---|---|---|---|
| Outcomes | 1 | 2 | 3 | 4 | 5 | 6 |
| ***HbA1c*** | ↓↑ | ↓↑ | ↓↑ | ↓* | ↓* | ↓* |

| | | | | | | |
|---|---|---|---|---|---|---|
| ***BMI*** | ↑* | | ↓↑ | ↑* | ↑* | ↑* |
| ***Daily Insulin Dose*** | ↓↑ | ↓↑ | ↓* | | | |
| ***Psychosocial*** | | | | | ↑* | |

Note: ↓↑ shows no significant effect: ↑ positive, ↓ negative. * Shows effect

BMI was increased in three (1,4,5,6) research except one (3). Article 3 could not find significant effect of intervention on BMI. Article 2 had found positive association between HbA1c and sedentary behavior. And insulin or injection therapy did not change according to physical activity or sedentary behavior.

There was a positive effect on quality of life, but the effect was shown in comparison between three and seven months. Self-management was reduced in adolescents with T1D and seen as a barrier in this study (5).

### 6.3.1 Other key findings

Participants engaged in a cycling test with limited sprint duration due to hypoglycemia risk in one study (1). In another study, parents monitored post-training glycemia to prevent hypoglycemia (4). Vigilant hypoglycemia monitoring was maintained during games; post-program, glucose levels were raised above 120 mg/dl with fruit juice (6). In contrast to other studies, this research revealed minimal hypoglycemia concerns and strong social confidence (5). Unlike social functioning or hypoglycemia worries, suboptimal self-management was more prominent (5). Interestingly, despite adolescence-related concerns, participants exhibited high social confidence, low post-MVPA (Moderate-vigorous physical activity) hypoglycemia worries, and improved blood sugar levels (5).

## 7 Discussion

It is widely accepted that regular physical activity (PA), as stated in clinical guidelines, provides numerous benefits for individuals living with Type 1 Diabetes (T1D) in terms of both physical and mental health (Mitchell et al., 2017; Ash et al., 2018). However, despite these recognized advantages, many people with T1D often fall short of the recommended daily dose of PA, which includes a minimum of 60 minutes of moderate to vigorous activity. This lack of participation not only leads to lower levels of physical engagement compared to their non-diabetic peers but also contributes to the adoption of sedentary behaviors, such as prolonged periods of sitting or

lying down while awake (MacMillan et al., 2016). As mentioned in the results section, this sedentary behavior has been found to be related to HbA1c (MacMillan et al., 2014; Urniaż, 2018). These sedentary habits are associated with adverse health outcomes, especially among children (Galler et al., 2011). While the positive effects of exercise on managing T1D, including improved glycemic control, reduced cardiovascular risks, and enhanced quality of life, are well-founded (Alazmi et al., 2022; Vartak et al., 2021), concerns regarding exercise-induced hypoglycemia persist among T1D patients (Tunar et al., 2012). This concern stems from the intricate process of balancing insulin doses and carbohydrate intake to maintain stable blood sugar levels (Vartak et al., 2021). The physiological and psychological changes during this developmental stage of adolescence can disrupt metabolic equilibrium and further intensify the complexities of T1D management (Lorentsen & Bergstad, 2005; Ash et al., 2018). This tried aimed to investigate the effects of interventions focusing on physical activity in individuals with T1D. While the exploration of glycemic control and biological outcomes was encompassed, the limited findings concerning psychosocial development stand out. The impact of physical activity only becomes evident after 12 weeks, underscoring the need for future research to extend intervention durations beyond 12 weeks.

## 7.1 Glycemic Control and Hypoglycemia

The findings across the studies reveal a diverse range of outcomes concerning the impact of physical activity interventions on glycemic control. While some articles indicate improvements in HbA1c levels (Petschnig et al., 2019; Ash et al., 2019; Mohammed et al., 2021), others underscore the absence of significant changes (Tunar et al., 2012; MacMillan et al., 2014; Ash et al., 2019). Notably, a specific study sheds light on a decrease in insulin dosages post-intervention within the exercise group, proposing a potential positive correlation between physical activity and insulin management (Tomar et al., 2014). As mentioned in the introduction, maintaining stable blood sugar levels is vital. This is intricately tied to dietary programs, insulin dosages, and daily movement. Achieving glycemic control mitigates the risk of hypoglycemia and enhances the individual's quality of life.

## 7.2 Body Mass Index

In 4 of the six articles, increasing body mass index (BMI) was observed following physical activity interventions (Tunar et al., 2012; Petschnig et al., 2020; Ash et al., 2019; Mohammed et al., 2021). As mentioned in the introduction section above, obesity poses a threat to children

with T1D (Alazmi et al., 2022). Children need to engage in exercise to maintain their BMI within healthy ranges. Creating awareness in children through a self-management model and sustainable programs can help achieve and maintain healthy BMI levels.

## 7.3 Psychosocial Effects

The studies underscore the significance of considering psychosocial dimensions. A common thread observed in various studies is the concern surrounding hypoglycemia risk (Tunar et al., 2012; Petschnig et al., 2020; Mohammed et al., 2021). In response, strategies involving insulin adjustments and meticulous monitoring were implemented during physical activities to mitigate this risk. Surprisingly, certain studies emphasize an enhancement in participants' quality of life, particularly in cases where interventions were sustained over extended durations (Ash et al., 2018). However, persistent challenges in self-management acted as barriers to engagement in physical activity among adolescents with T1D (Ash et al., 2018; Lorentsen & Bergstad, 2005). Given the continual need for control in T1D, the psychological well-being of patients is of paramount importance. This, in turn, bolsters their self-efficacy and confers advantages in daily life. Apart from Ash et al.'s (2019) study, other articles have primarily focused on the medical outcomes of physical activity interventions. However, providing informative education alongside physical activity interventions or creating social environments where children can express themselves may help increase awareness in children.

## 7.4 Self-Management Model

This discussion establishes a connection with Bandura's social cognitive theory, which offers a relevant framework for interpreting the implications of the presented findings. The foundational principles of this theory underscore the importance of motivation and self-control in effecting complex behavior change, encapsulating the intricate process (Bandura, 2004). This model may contribute to changing the habits of T1D children for the better.

Within the purview of this theoretical perspective, the discussed results mirror the intricacy of promoting physical activity interventions for individuals with Type 1 Diabetes (T1D). Shifting behavior patterns necessitates the aspiration for change and the capability to monitor one's actions, discern triggers prompting specific behaviors, and cultivate self-regulation for achieving better outcomes (Bandura, 2004). In managing T1D, this approach resonates particularly with the challenges participants encounter, including apprehensions surrounding

hypoglycemia and the complexities of self-management. The findings reflect the theory's assertion that individuals must develop self-monitoring, self-motivation, and self-guidance skills to maintain positive health behaviors (Bandura, 2004). As observed in certain studies, the implementation of insulin adjustments and meticulous tracking during physical activities emphasizes the significance of self-regulation and control in minimizing risks and maximizing benefits (Petschnig et al., 2020; Ash et al., 2019). When the self-management model is applied to children's lives, it can provide them with the ability to minimize eating disorders and engage in self-care. This may help reduce the risks of obesity and hypoglycemia.

Moreover, proactively managing one's health over time aligns harmoniously with the enduring nature of T1D management, which necessitates sustained physical activity interventions. The evidence pointing to positive effects emerging after extended durations resonates with Bandura's emphasis on gradual and consistent change over time (Bandura, 2004). Furthermore, the premise that this approach can be tailored to unique needs concurs with the outcomes reported across distinct studies, reflecting the diversity of responses among participants.

This self-management perspective also aligns with the modern digital age, where interventions can be disseminated through the Internet, reaching a wider audience regardless of location or preferred timing (Bandura, 2004). As such, the findings underscore this approach's potential adaptability and applicability in various contexts, rendering it a valuable tool for promoting physical activity among individuals with T1D (Ayar et al., 2021). Its applicability in various contexts can become an opportunity for children in today's technological age.

In conclusion, this discussion contextualizes the study's outcomes within Bandura's social cognitive theory, elucidating the interplay among motivation, self-regulation, and behavior change concerning physical activity interventions for individuals with T1D. As evidenced by the studies, addressing psychosocial dimensions and self-management challenges is essential. Researchers and healthcare practitioners embracing this approach can tailor interventions to align with each individual's unique requirements and circumstances, thereby fostering sustainable positive health outcomes.

## 8 Limitations

A limited number of articles were reviewed (n=6). It is imperative to exercise caution when extrapolating and applying the outcomes, and the small sample size should not be overlooked. The selected articles predominantly focus on medical results, making it challenging to accurately discern psychosocial effects. This limitation adds a constraint to the study. While the study's primary aim is to observe intervention effects, it should be noted that the study conducted by MacMillan et al. (2014) lacks an intervention program. Although the article results have contributed to the study, its exclusion from the criteria for not meeting inclusion standards has diminished its reliability. Furthermore, none of the articles except for Ash et al. (2019) have conducted follow-up studies. This is one of the essential considerations that researchers should keep in mind.

Secondly, the utilized articles comprise quantitative studies; however, to avoid confusion, the scope of the results was indicated without employing numerical data. Lastly, the low number of utilized articles has reduced the generalizability of the study's findings.

## 9 Future Research

In line with the aim of this study, numerous articles were examined, yielding several implications for future research. Firstly, forthcoming investigations should focus more on the impact of physical activity on glycemic control. If such an effect is to be explored, intervention durations should exceed twelve weeks. As noted by Quirk et al. (2014), greater attention should be paid to participants' psychosocial development. Future studies should also pay attention to the diversity of age, gender, and physical activity within the sample. Lastly, a notable observation from this study is that patients experience improved quality of life when provided with easily accessible informative education related to Type 1 Diabetes, such as online education. This is exemplified by the non-online version of the intervention conducted by Ash et al. (2019). In addition to interventions, more emphasis can be placed on informative educational components.

## 10 Conclusion

The intervention of physical activity has shown a positive impact on managing blood sugar levels. However, the intervention is more effective when carried out for longer than twelve

weeks. The fear of low blood sugar sometimes causes participants to back away from the intervention. Nevertheless, precautions can be taken before and after the intervention to control this, and by consistently monitoring blood sugar levels, the risk of low blood sugar can be decreased. To improve the quality of life for children and teenagers with diabetes, it is important to help them feel confident in managing their condition and provide them with educational information. Keeping blood sugar levels stable requires staying active, improving eating habits, and taking charge of self-regulation.

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# 12 Appendices

## 12.1 Appendix A

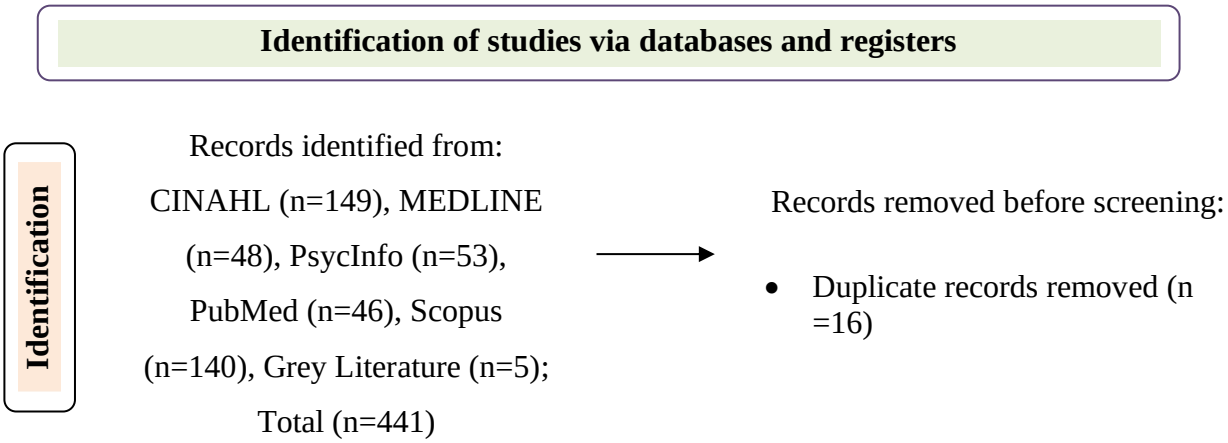
*Final search terms*

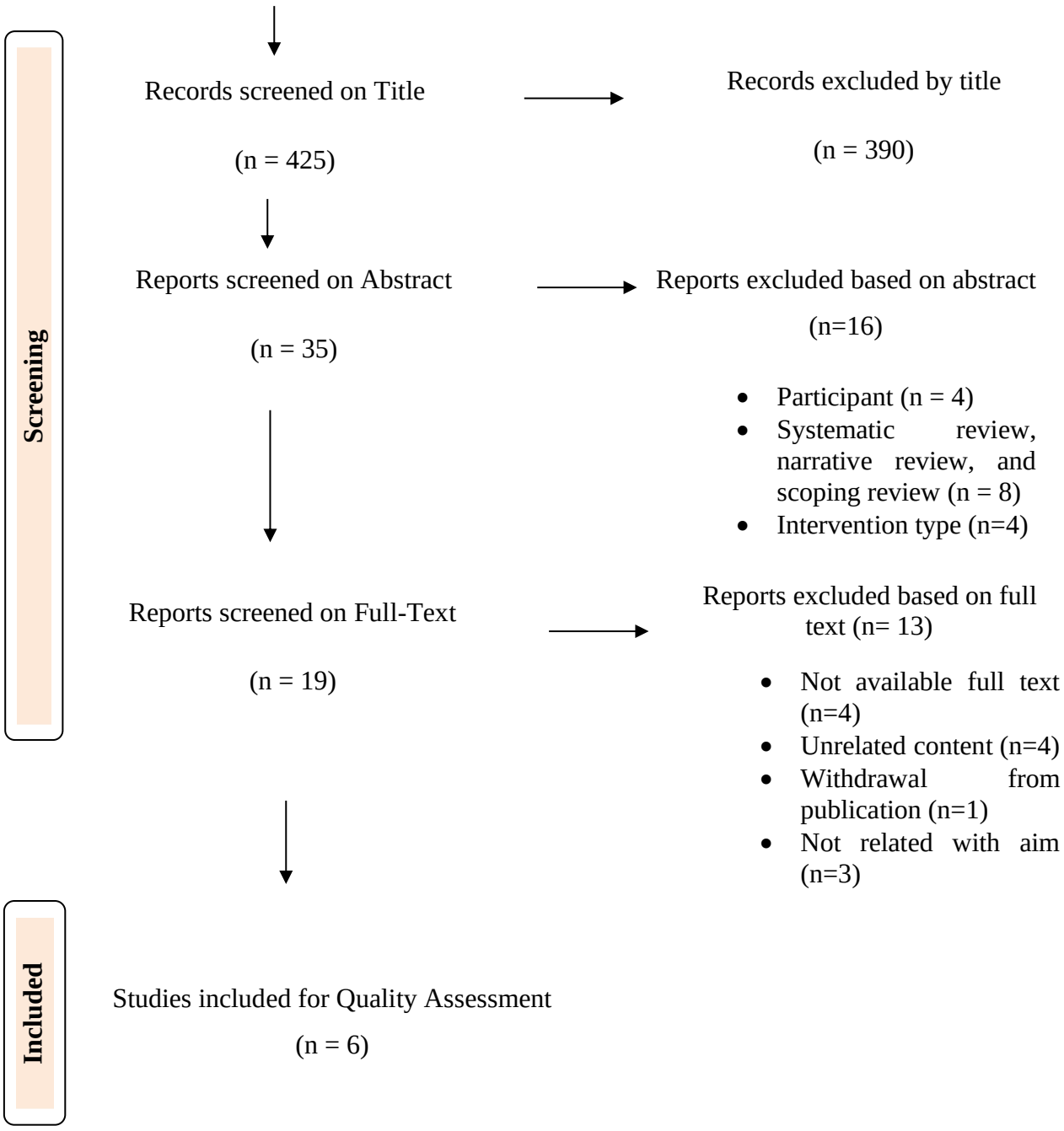
| Search Strings | Database | Result |
|---|---|---|
| (type 1 diabetes mellitus or type 1 diabetes or diabetes mellitus type 1 or diabetes type 1) AND (“physical activity" or exercise or fitness or "physical exercise" or sport or walking or cy-cling ) AND ( children or kids or youth or child ) AND intervention | ***CINAHL with full text*** Limit to published date between 2012-2023, peer-reviewed articles and English language | 149 |
| noft("type 1 diabetes mellitus" OR T1D OR type 1 diabetes) AND noft("physical activity" OR exercise OR fitness OR "physical exercise" OR sport OR walking OR cycling) AND noft(children OR kids OR youth OR child) AND noft(intervention) | ***PsycInfo*** Limit to published date between 2012-2023, peer-reviewed articles and English language | 53 |
| (type 1 diabetes mellitus or type 1 diabetes or diabetes mellitus type 1 or diabetes type 1) AND (“physical activity" or exercise or fitness or "physical exercise" or sport or walking or cycling) AND (children or kids or youth or child) AND intervention | ***MEDLINE*** Limit to published date between 2012-2023, peer-reviewed articles and English language | 48 |
| **(((**"type 1 diabetes mellitus" or "type 1 diabetes" or "diabetes mellitus type 1" or "diabetes type 1") AND ("physical activity" or exercise or fitness or "physical exercise" or sport or walking or cycling)) AND (children or kids or youth or child)) AND (intervention) | ***PubMed*** Limit to published date between 2012-2023, peer-reviewed articles and English language | 46 |
| ( TITLE-ABS-KEY ( "type 1 diabetes mellitus" OR "type 1 diabetes" OR "diabetes mellitus type 1" OR "diabetes type | ***Scopus*** | 140 |

| | |
|---|---|
| 1" ) AND TITLE-ABS-KEY ( "physical activity" OR exercise OR fitness OR "physical exercise" OR sport OR walking OR cycling ) AND TITLE-ABS-KEY ( children OR kids OR youth OR child ) AND TITLE-ABS-KEY ( intervention ) ) AND ( LIMIT-TO ( PUBYEAR , 2023 ) OR LIMIT-TO ( PUBYEAR , 2022 ) OR LIMIT-TO ( PUBYEAR , 2021 ) OR LIMIT-TO ( PUBYEAR , 2020 ) OR LIMIT-TO ( PUBYEAR , 2019 ) OR LIMIT-TO ( PUBYEAR , 2018 ) OR LIMIT-TO ( PUBYEAR , 2017 ) OR LIMIT-TO ( PUBYEAR , 2016 ) OR LIMIT-TO ( PUBYEAR , 2015 ) OR LIMIT-TO ( PUBYEAR , 2014 ) OR LIMIT-TO ( PUBYEAR , 2013 ) OR LIMIT-TO ( PUBYEAR , 2012 ) ) AND ( LIMIT-TO ( LANGUAGE , "english" ) ) | Publish the date selected manually, peer-reviewed articles and English language |
| **Total** | **436** |

## 12.2 Appendix B

*Flowchart*






## 12.3 Appendix C

*Data extraction protocol*

| | |
|---|---|
| **General Information** | - No. of the article<br>- Author<br>- Year<br>- Title<br>- Journal<br>- Country |
| **Methodology** | - Study Design (RCT, CCT, COHORT) |
| **Purpose** | - Aim of the study (transcription)<br>- Research question(s) (transcriptions)<br>- Hypotheses (transcriptions) |
| **Ethical Considerations** | - Were the ethics procedures described in detail? (Yes/No)<br>- [Consider: informed consent, child assent and ethical approval] |
| **Population** | - Recruitment method (random, convenient, purposeful sampling)<br>- Type 1 Diabetes diagnose (Yes/No)<br>- Additional information related to the experimental group<br>- Mean age of the experimental group (years/months/ unspecified)<br>- Age range<br>- Sample size of the experimental group<br>- Comparator (Y/N)<br>- Description of the comparator (no exercise/usual activities)<br>- Sample size of the comparator<br>- Number of drop-outs<br>- Reason for drop-out reported (Y/N)<br>- Total sample size after drop-outs (intervention + comparator) |

| | |
|---|---|
| **Intervention** | - Type of physical Intervention<br>- Aim or focus of the intervention<br>- Duration of the Intervention (in minutes, days, weeks, or months)<br>- Total number of sessions (blank if unspecified) |
| **Setting** | - Where was the intervention conducted? / Was there a trainer throughout the activity<br>- Were there any special diet and insulin injection programme? (Y/N) |
| **Outcome measures** | - Do they conduct a follow up (Yes/No)<br>- Name of measurement tools<br>- Data collection methods (Self-reported data, Assessment/Screening, Medical records) |
| **Findings/Results** | - Were the drop-outs accounted for when reporting results? (Y/N)<br>- Name of the analysis method<br>- What were the transcriped results?<br>- Were the results statistically significant? (Y/N)<br>- What were the results? (Positive/ Negative/ Non-effect)<br>- Pre-measure (mean±SD), post-measure (mean±SD), follow-up measure(mean±SD) |
| **Methodological Rigor** | - What are the main limitations of the study? (Ethical considerations, sampling bias, intervention/performance bias, measurement/detection bias) |
| **Conclusion** | - Were conclusions appropriate given the study methods and results? (Yes/No)<br>- What were the conclusions? (transcriptions) |

| | |
|---|---|
| **Quality assessment** | - Is the article of strong, moderate or weak quality? |

## 12.4 Appendix D

*Quality of articles and design*

| Author | A. Selection Bias (Q1) | A. Selection Bias (Q2) | A. SCORE | B. Study design | B. SCORE | C. Confounders (Q1) | C. Confounders (Q2) | C. SCORE | D. Blinding (Q1) | D. Blinding (Q2) | D. SCORE | E. Data collection methods (Q1) | E. Data collection methods (Q2) | E. SCORE | F. Withdrawals and drop-outs (Q1) | F. Withdrawals and drop-outs (Q2) | F. SCORE | Global Rating |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tunar et al. (2012) | 1 | 1 | * | RCT | * | 2 | - | * | 3 | 3 | ** | 1 | 1 | * | 2 | 1 | * | Strong |
| MacMillan et al. (2014) | 1 | 1 | * | CCT | * | 1 | 1 | * | 3 | 3 | ** | 1 | 2 | ** | 1 | 1 | * | Weak |
| Tomar et al. (2014) | 2 | 1 | ** | RCT | * | 2 | - | * | 2 | 2 | * | 1 | 1 | * | 1 | 1 | * | Strong |
| Petschnig et al. (2020) | 1 | 1 | * | RCT | * | 2 | - | * | 3 | 3 | ** | 1 | 1 | * | 1 | 2 | ** | Strong |
| Ash et al. (2019) | 1 | 1 | * | COHORT | ** | 2 | - | * | 3 | 3 | ** | 1 | 3 | ** | 1 | 4 | *** | Moderate |
| Mohammed et al. (2021) | 2 | 2 | ** | RCT | * | 2 | - | * | 1 | 1 | * | 1 | 3 | ** | 1 | 1 | * | Strong |

** = Strong, ** = Moderate, *** = Weak*