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Original Research

Barriers to Exercise in Adults With Type 1 Diabetes and Insulin Resistance

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Key Messages

- The presence of insulin resistance (IR) is associated with lower physical activity levels and greater barriers to physical activity in individuals with type 1 diabetes (T1D).
- Glycemic factors, specifically hypoglycemia, are the most salient barriers to exercise in individuals with T1D with IR, but not in individuals with T1D without IR.

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ABSTRACT

Objective: Our aim in this study was to assess attitudes toward exercise and quality of life (QoL) in adults with type 1 diabetes (T1D) with and without insulin resistance (IR).
Methods: We pooled baseline pretreatment data from a subset of individuals with T1D from 2 randomized controlled trials. Estimated glucose disposal rate (eGDR), a validated surrogate marker of IR, was calculated using an established formula to classify individuals according to IR status with a cut-point of <6 mg/kg/min for the determination of IR. Self-reported barriers to exercise were obtained using a validated questionnaire, the Barriers to Physical Activity in T1D (BAPAD-1). In addition, QoL was determined using the 36-item Short Form (SF-36) questionnaire. Differences between dichotomized variables were assessed using the independent t test, Mann–Whitney *U* test, or Fisher exact test. Linear regression was employed to explore the association of eGDR with BAPAD-1 and QoL scores, with sequential adjustment for potential confounders.
Results: Of the 85 individuals included in our study, 39 were classified as having IR. The mean BAPAD-1 total score was higher for individuals with IR (IR: 3.87±0.61; non-IR: 2.83±0.55; $p<0.001$). The highest exercise barrier scores for individuals with IR were risk of hypoglycemia (5.67±1.26) and risk of hyperglycemia (5.23±1.20), whereas the highest scoring exercise barrier scores for non-IR individuals were not diabetes-related, with low level of fitness (3.91±1.26) and physical health status, excluding diabetes (3.67±1.48), ranked highest. QoL scores were comparable between groups ($p>0.05$).
Conclusions: Risk of hypoglycemia was the greatest barrier to exercise in individuals with T1D with IR, whereas non–diabetes-related barriers to exercise were more salient in individuals with T1D without IR.

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RÉSUMÉ

Objectif : L'objectif était d'examiner les attitudes envers l'exercice et, par conséquent, la qualité de vie (QdV) des adultes diabétiques de type 1 (DT1), insulinorésistants (IR) ou non insulinorésistants (non-IR).
Méthodes : Nous avons mis en commun les données initiales préalables au traitement d'un sous-ensemble d'individus atteints du DT1 de 2 essais cliniques à répartition aléatoire (ERA). Nous avons calculé l'estimation du débit de perfusion du glucose (eDPG), un marqueur de substitution validé de la résistance à l'insuline (RI), à l'aide d'une formule établie pour classifier les individus en fonction de leur état, IR ou non-IR, selon un seuil de < 6 mg/kg/min pour la détermination de la RI. Nous avons obtenu les obstacles à l'exercice auto-déclarés grâce à un questionnaire valide, le *Barriers to Physical Activity in T1D* (BAPAD-1). De plus, nous avons déterminé la QdV grâce au questionnaire *36-item short form (SF-36)*. Nous avons évalué les différences entre les variables dichotomiques au moyen de tests t pour échantillons indépendants, les tests U de Mann-Whitney ou les tests exacts de probabilité de Fisher. Nous avons eu recours à la régression linéaire pour examiner l'association de l'eDPG entre les scores de BAPAD-1 et les scores de QdV après ajustement séquentiel des facteurs confusionnels potentiels.
Résultats : Au sein des 85 individus sélectionnés, nous en avons classifié 39 (n = 39) en individus IR. Le score total moyen de BAPAD-1 était plus élevé chez les individus IR (IR 3,87 ± 0,61 *vs* non-IR 2,83 ± 0,55; P < 0,001). Les scores les plus élevés aux obstacles à l'exercice chez les individus IR étaient le risque d'hypoglycémie (5,67 ± 1,26) et le risque d'hyperglycémie (5,23 ± 1,20), alors que les scores les plus élevés aux obstacles à l'exercice chez les individus non-IR n'étaient pas reliés au diabète; le faible niveau de forme physique (3,91 ± 1,26) et l'état de santé physique, à l'exclusion du diabète (3,67 ± 1,48), obtenaient les scores les plus élevés. Les scores de QdV étaient comparables entre les groupes (P > 0,05).
Conclusions : Le risque d'hypoglycémie était le plus grand obstacle à l'exercice chez les individus atteints du DT1 et IR, tandis que les obstacles à l'exercice non reliés au diabète étaient plus saillants chez les individus atteints du DT1 et non-IR

Introduction

Regular participation in physical activity reduces the risk of developing insulin resistance (IR), metabolic syndrome, and progression to overt type 2 diabetes (T2D) [1]. In individuals with type 1 diabetes (T1D), regular physical activity also improves features of metabolic syndrome, including IR [2], and lowers the risk of long-term health complications [3]. A recent large, cross-sectional survey of 18,028 adults with T1D demonstrated that ~60% of individuals with T1D did not achieve the recommended physical activity levels of ≥150 minutes of moderate-to-vigorous physical activity per week [3], a finding that supports some [4,5], but not all [6], earlier studies. Previously, fear of hypoglycemia and a lack of knowledge about managing diabetes around exercise have been reported as salient barriers to exercise [7–9], but it has yet to be established whether these perceived barriers differ between individuals with and without IR. Furthermore, T1D has consistently been shown to be associated with reduced quality of life (QoL) [10,11], and exercise [12] and IR [13] have been identified as major mediating factors.

IR is highly prevalent within the T1D population and represents a strong independent risk factor for diabetes complications [14–16]. Although individuals with T1D are more prone to IR than those without diabetes [17], participating in physical activity improves insulin sensitivity [18,19]. Given the health benefits associated with physical activity, individuals with T1D with IR are likely to benefit greatly from regular participation in physical activity. However, little is known about the attitudes toward physical activity or QoL in individuals with T1D with associated IR. Existing research has focussed principally on T1D as a single clinical entity when considering attitudes and barriers to exercise and QoL [7,9,20,21]. In the general population, obesity is associated with lower physical activity levels and poorer QoL [22], suggesting that some barriers to exercise and QoL outcomes are weight-specific. Furthermore, IR is generally associated with increased insulin dose requirements and poorer glycemic management in T1D [23], both of which increase the burden of disease [24]. As such, it is possible that individuals with T1D and IR have greater barriers to physical activity than those with T1D without IR. To the best of our knowledge, however, no research has explored whether attitudes toward physical activity in individuals with T1D are mediated by IR and how it affects QoL. This information is important for the future design of individualized and person-centred physical activity interventions that target those with T1D at high risk of complications. Therefore, the aim of this study was to better understand attitudes toward exercise in individuals with T1D with and without IR, while also investigating the impact on QoL.

Methods

Study population

We pooled data from 2 randomized controlled trials (RCTs; Clinical Trial Registration nos. ISRCTN40811115 and NCT05231642), each of which received approval from local National Health Service research ethics committees (REC reference nos. 17/NE/0244 and 21/WA/0381). Briefly, ISRCTN40811115 was an RCT investigating the impact of omega-3 supplementation on glycemic management in T1D, and NCT05231642 was an RCT investigating exploring interpersonal postprandial glucose responses in T1D. In both RCTs, participants were recruited from the Yorkshire, Humber, and northeast regions of the United Kingdom both in-clinic and through university-led advertisments, and written informed consent was obtained from all participants. We used baseline pretreatment data only from the 2 RCTs. In the present analysis, we included 85 participants who met the inclusion criteria, as described elsewhere [25,26], including a classical presentation of T1D, age between 18 and 50 years, a diabetes duration of ≥5 years, and treatment on a stable (>12 months) basal-bolus insulin regimen delivered through multiple daily injections or continuous subcutaneous insulin infusion. None of the study participants had clinically established diabetes-related complications.

Table 1
Characteristics of the study population stratified by IR status

Characteristics	All data	IR status		p Value
		IR	Non-IR	
Number	85	39 (46%)	46 (54%)	—
Age, years	28.60±5.44	30.66±4.99	26.86±5.23	<0.001 *
Sex male	43 (51%)	22 (56%)	21 (46%)	0.22 ‡
BMI, kg/m^2	26.52±3.36	28.21±3.21	25.09±2.79	<0.001 *
A1C, mmol/mol	60.96 [13.3]	67.15 [22.16]	56.43 [9.10]	<0.001†
A1C, %	7.73 [1.22]	8.29 [2.03]	7.32 [0.83]	<0.001 †
Length of diagnosis, years	16.27 [2.90]	19.17 [12.94]	14.58 [11.38]	0.003 †
Hypertensive	44 (51.80%)	39 (100%)	5 (10.90%)	<0.001 ‡
Bolus insulin aspart	54 (63.50%)	23 (59%)	31 (67.40%)	0.282 ‡
TDD, IU	45 [8]	46 [9]	42 [7]	<0.001 †
No exercise	38 (45%)	28 (72%)	10 (22%)	0.004 ‡
Moderate exercise	32 (38%)	13 (33%)	19 (41%)	0.298 ‡
Vigorous exercise	15 (18%)	9 (23%)	6 (13%)	0.178 ‡

A1C, glycated hemoglobin; *BMI*, body mass index; *IR*, insulin resistance; *TDD*, total daily insulin dose requirements.
Notes: Normally distributed variables are presented as mean ± standard deviation, non-normally distributed variables are presented as median [interquartile range], and categorical variables are presented as number (%).
* Independent t test.
† Mann–Whitney *U* test.
‡ Fisher exact test.

Data collection and study procedures

We performed cross-sectional analyses using baseline pre-treatment data across each RCT. Clinical information obtained included age, sex, body mass index (BMI), glycated hemoglobin (A1C), hypertension (HTN) status, insulin regimen, estimated glucose disposal rate (eGDR) and self-reported physical activity levels. Participants were defined as hypertensive if blood pressure was ≥140/90 mmHg, if they had a pre-existing diagnosis of HTN, or if they were prescribed antihypertensive drugs. Participants were classified by IR status using the eGDR—a validated surrogate marker of IR—formulated using BMI, A1C, and HTN status as follows: eGDR = 19.02 − (0.22 × BMI [kg/m^2] − (3.26 × HTN) − (0.61 × A1C [%]), where HTN=1 when yes and HTN=0 when no [27]. Patients were informed about their IR status after completion of the research procedures.

We assessed self-reported attitudes to exercise using the validated Barriers to Physical Activity in T1D (BAPAD-1) questionnaire [28,29], which has been described in detail in previous work [29–31]. In summary, the BAPAD-1 scale consists of 11 equally weighted diabetes-specific items, with answers coded on a 7-level rating scale ranging from extremely unlikely to extremely likely to represent the likelihood of individuals practicing regular physical activity during the next 6 months [29,31].

QoL was determined using the 36-item Short Form questionnaire (SF-36) [32]—a tool that has been validated previously in individuals with diabetes [33]. The SF-36 assesses both physical and mental domains in 8 multiple-item scores: physical functioning, limitations due to physical problems, social functioning, bodily pain, general mental health (psychological distress and well-being), limitations due to emotional problems, vitality (energy and fatigue), and general health perceptions. All domains contribute differently to the scoring for both measures [34]. Scores from different domains were converted and aggregated using a scoring key to obtain a score indicating a range from low to high QoL.

Statistical analysis

Descriptive information for each variable was calculated and assessed for normality. Normally distributed variables are reported as mean ± standard deviation, non-normally distributed variables are reported as median (interquartile range), and categorical variables are reported as frequency (%). Beta coefficients with confidence intervals (CIs) were presented whenever appropriate. The

Table 2
Barriers to physical activity in individuals with T1D stratified by eGDR (IR status)

Barrier to physical activity	All data	IR status		p Value
		IR	Non-IR	
1. Loss of control over your diabetes	3.49±1.71	4.33±1.83	2.78±1.24	0.004 *
2. Risk of hypoglycemia	4.24±1.78	5.67±1.26	3.02±1.15	<0.001 †
3. Fear of being tired	1.81±0.93	1.97±1.06	1.67±0.79	0.138 †
4. Fear of hurting yourself	1.92±0.97	2.08±0.96	1.78±0.96	0.355 †
5. Fear of suffering a heart attack	2.61±1.57	3.49±1.72	1.87±0.93	<0.001 †
6. A low level of fitness	4.08±1.31	4.28±1.36	3.91±1.26	0.849 †
7. Presence of diabetes	3.80±1.40	4.46±1.27	3.24±1.27	0.005 †
8. Risk of hyperglycemia	4.14±1.63	5.23±1.20	3.22±1.35	<0.001 †
9. Physical health status excluding diabetes	3.51±1.41	3.31±1.34	3.67±1.48	0.659 †
10. Weather conditions	3.49±2.38	3.87±1.15	3.17±3.04	0.008 †
11. Location of a gym	2.76±1.14	2.87±1.08	2.67±1.19	0.730 †
Standardized total score	3.31±0.77	3.87±0.61	2.83±0.55	<0.001 ‡

eGDR, estimated glucose disposal rate; *IR*, insulin resistance; *T1D*, type 1 diabetes.
Note: Data presented as mean ± standard deviation.
* Independent t test.
† Fisher exact test.
‡ Mann–Whitney *U* test.

Table 3
Association between eGDR and BAPAD-1 subscales

eGDR	Model 1		Model 2		Model 3	
	β (95% CI)	p Value	β (95% CI)	p Value	β (95% CI)	p Value
1. Loss of control over your diabetes	−0.629 (−1.13 to −0.65)	<0.001 *	−0.522 (−0.96 to −0.52)	<0.001 *	−0.498 (−0.92 to −0.49)	<0.001 *
2. Risk of hypoglycemia	−0.817 (−1.29 to −0.95)	<0.001 *	−0.733 (−1.19 to −0.81)	<0.001 *	−0.709 (−1.16 to −0.78)	<0.001 *
3. Fear of being tired	−0.220 (−1.13 to −0.02)	0.044 †	−0.165 (−0.91 to −0.05)	0.077	−0.126 (−0.82 to −0.16)	0.183
4. Fear of hurting yourself	−0.291 (−1.26 to −0.21)	0.007 ‡	−0.278 (−1.15 to −0.25)	0.003 ‡	−0.268 (−1.12 to −0.24)	0.003 ‡
5. Fear of suffering a heart attack	−0.568 (−1.16 to −0.61)	<0.001 *	−0.471 (−0.99 to −0.48)	<0.001*	−0.446 (−0.96 to −0.43)	<0.001 *
6. A low level of fitness	−0.281 (−0.91 to −0.13)	0.009 ‡	−0.115 (−0.58 to 0.15)	0.249	−0.174 (−0.69 to 0.04)	0.082
7. Presence of diabetes	−0.461 (−1.14 to −0.46)	<0.001*	−0.341 (−0.90 to −0.28)	<0.001*	−0.335 (−0.89 to −0.27)	<0.001 *
8. Risk of hyperglycemia	−0.710 (−1.29 to −0.83)	<0.001*	−0.601 (−1.11 to −0.69)	<0.001*	−0.581 (−1.08 to −0.66)	<0.001 *
9. Physical health status excluding diabetes	0.148 (−0.12 to 0.63)	0.176	0.220 (0.07 to 0.69)	0.019†	0.262 (0.15 to 0.76)	0.004 ‡
10. Weather conditions	−0.237 (−0.46 to −0.03)	0.029 †	−0.177 (−0.37 to −0.01)	0.061	−0.188 (−0.38 to −0.01)	0.043 †
11. Location of a gym	−0.094 (−0.67 to −0.26)	0.392	−0.111 (−0.63 to 0.16)	0.237	−0.083 (−0.57 to 0.22)	0.374

BAPAD-1, Barriers to Physical Activity in Type 1 Diabetes; *CI*, confidence interval; *eGDR*, estimated glucose disposal rate.
Notes: Model 1 unadjusted; Model 2 adjusted for age, sex, and length of diagnosis; Model 3 adjusted for age, sex, duration of diabetes, and exercise participation.
* Significant association at p<0.001.
† Significant association at p<0.05.
‡ Significant association at p<0.01.

cohort was stratified according to eGDR into IR status, with a cut-point of <6 mg/kg/mL for the determination of IR, as reported elsewhere [35]. Continuous variables were examined using independent t tests for normally distributed variables and Mann−Whitney *U* tests for non-normally distributed variables, and categorical variables were examined with Fisher exact tests. Linear regression was used to investigate the association between eGDR and BAPAD-1 and QoL (SF-36) questionnaires, respectively, with sequential adjustment for confounders (age, sex, diabetes duration, exercise participation levels) using the subscores for each domain. Data analysis was performed using SPSS version 28 (IBM Corp, Armonk, New York, United States), with p<0.05 considered statistically significant.

Results

The clinical characteristics of the cohort stratified by IR status are presented in Table 1. A total of 85 individuals (39 with IR and 46 without IR) were included in the analysis. Individuals with IR were more likely to be older with a longer duration of diabetes, higher total daily insulin dose, an increased prevalence of hypertension, and lower levels of exercise participation (p<0.05; Table 1).

The mean BAPAD-1 total score was higher for individuals with IR (IR: 3.87±0.61; non-IR: 2.83±0.55; p<0.001; Table 2). The highest exercise barrier scores for IR were risk of hypoglycemia (IR: 5.67±1.26), risk of hyperglycemia (IR: 5.23±1.20), presence of diabetes (IR: 4.46±1.27), and loss of diabetes management (IR: 4.33±1.83). The highest scoring exercise barrier scores for non-IR were not diabetes-related with low level of fitness (3.91±1.26) and physical health status excluding diabetes (3.67±1.48) listed as the most salient barrier in non-IR (Table 2). Table 3 presents the unadjusted and adjusted associations between IR status and BAPAD-1 subscales. Significant associations were observed between eGDR and BAPAD-1 subscales (i.e. loss of control over your diabetes, risk of hypoglycemia, fear of hurting yourself, fear of suffering a heart attack, presence of diabetes, and risk of hyperglycemia) (p<0.05; Table 3). The strongest association was for risk of hypoglycemia in unadjusted and adjusted models (Model 1: β=−0.817; Model 2: β=−0.733; Model 3: β=−0.709; p<0.001; Table 3). These associations remained robust after adjustment for age, sex, diabetes duration, and exercise participation, except fear of being tired and a low level of fitness in Model 2 and Model 3, and weather conditions in Model 2 (p>0.05; Table 3). Furthermore, significant associations were observed between fear of being tired, a low level of fitness, and weather conditions with eGDR. The subscale for location of a gym was not significant with eGDR (p>0.05; Table 3).

The mean SF-36 subscale scores are presented in Table 4. No differences were observed across any physical or mental components of the SF-36 when assessing the cohort stratified by IR status. Table 5 presents the unadjusted and adjusted associations between eGDR and SF-36 subscales. No significant associations were observed in SF-36 subscales and eGDR after unadjusted and adjusted models for age, sex, length of diagnosis, and exercise participation, with the exception of emotional problems, which was significantly associated with eGDR after sequential adjustment (Table 5).

Table 4
QoL scores for individuals with T1D stratified by eGDR (IR status)

	All data	IR status		p Value
		IR	Non-IR	
1. PF_NBS	48.00 (20.00)	52.00 (20.00)	43.00 (20.25)	0.733 *
2. RP_NBS	44.00 (27.00)	48.00 (25.00)	39.00 (29.00)	0.423 *
3. BP_NBS	42.00 (22.00)	42.00 (21.00)	38.00 (22.00)	0.919 *
4. GH_NBS	41.02±11.64	41.46±12.36	40.65±11.13	0.752 †
5. VT_NBS	43.75±12.20	44.08±12.95	40.48±11.67	0.823 †
6. SF_NBS	42.00 (30.00)	42.00 (30.00)	39.50 (25.00)	0.520 *
7. RE_NBS	46.00 (31.00)	49.00 (28.00)	37.00 (28.75)	0.054 *
8. MH_NBS	46.00 (23.00)	46.00 (21.00)	43.00 (23.00)	0.527 *
9. PCS	43.81±11.63	43.67±11.69	43.93±11.69	0.916 †
10. MCS	40.82±14.74	42.85±15.77	39.11±13.75	0.247 †

BP, bodily pain; *eGDR*, estimated glucose disposal rate; *GH*, general health; *IR*, insulin resistance; *MCS*, mental component summary; *MH*, mental health; *NBS*, norm-based scores; *PCS*, physical component summary; *PF*, physical functioning; *QoL*, quality of life; *RE*, role limitations due to emotional problems; *RP*, role limitation due to physical health; *SF*, social functioning; *T1D*, type 1 diabetes; *VT*, vitality.
Notes: Normally distributed variables are presented as mean ± standard deviation; non-normally distributed variables are presented as median (interquartile range); and categorical variables are presented as frequency (%).
* Mann−Whitney *U* test.
† Independent t test.
‡ Fisher exact test.

Discussion

To our knowledge, this is the first study to explore attitudes toward exercise and QoL in individuals with T1D with and without IR. We found that individuals with T1D with IR reported lower exercise participation levels and greater barriers to exercise than their counterparts without IR. Furthermore, we found that the main

Table 5
Association between eGDR (IR status) and QoL in T1D

eGDR	Model 1		Model 2		Model 3	
	β (95% CI)	p Value	β (95% CI)	p Value	β (95% CI)	p Value
1. PF_NBS	0.003 (−0.04 to 0.05)	0.893	−0.001 (−0.03 to 0.04)	0.962	−0.002 (−0.04 to 0.04)	0.923
2. RP_NBS	−0.006 (−0.05 to 0.03)	0.758	−0.007 (−0.04 to 0.03)	0.694	−0.010 (−0.04 to 0.03)	0.584
3. BP_NBS	0.003 (−0.04 to 0.04)	0.880	−0.006 (−0.04 to 0.03)	0.765	−0.010 (−0.05 to 0.03)	0.615
4. GH_NBS	−0.005 (−0.05 to 0.04)	0.833	−0.017 (−0.06 to 0.02)	0.396	−0.023 (−0.06 to 0.02)	0.239
5. VT_NBS	0.009 (−0.04 to 0.05)	0.699	0.001 (−0.04 to 0.04)	0.953	−0.004 (−0.05 to 0.04)	0.828
6. SF_NBS	0.000 (−0.04 to 0.04)	0.988	−0.014 (−0.05 to 0.02)	0.379	−0.022 (−0.06 to 0.01)	0.195
7. RE_NBS	−0.024 (−0.06 to 0.01)	0.153	−0.029 (−0.06 to −0.001)	0.043*	−0.032 (−0.06 to −0.003)	0.032*
8. MH_NBS	−0.003 (−0.04 to 0.04)	0.862	−0.018 (−0.05 to 0.02)	0.286	−0.022 (−0.06 to 0.01)	0.220
9. PCS	0.009 (−0.04 to 0.06)	0.692	0.007 (−0.03 to 0.05)	0.715	0.004 (−0.04 to 0.05)	0.847
10. MCS	−0.012 (−0.05 to 0.02)	0.495	−0.025 (−0.06 to 0.001)	0.112	−0.031 (−0.06 to 0.002)	0.062

BP, bodily pain; *CI*, confidence interval; *eGDR*, estimated glucose disposal rate; *GH*, general health; *IR*, insulin resistance; *MCS*, mental component summary; *MH*, mental health; *NBS*, norm-based scores; *PCS*, physical component summary; *PF*, physical functioning; *QoL*, quality of life; *RE*, role limitations due to emotional problems; *RP*, role limitation due to physical health; *SF*, social functioning; *T1D*, type 1 diabetes; *VT*, vitality.
Notes: Model 1 was unadjusted; Model 2 was adjusted for age, sex, and length of diagnosis; Model 3 was adjusted for age, sex, length of diagnosis, and exercise participation.
* Significant association at $p<0.05$.

barriers to exercise differ between individuals with T1D with and without IR; in our cohort diabetes-specific factors, specifically fear of hypoglycemia, were the most salient barriers to exercise in individuals with T1D with IR, whereas fitness and non–diabetes-specific physical health were the greatest barriers to exercise in individuals with T1D without IR. These findings remained robust after adjusting for age, gender, and diabetes duration.

We found that fear of hypoglycemia had the strongest association with eGDR. Findings from other studies, including those employing the BAPAD-1, demonstrated that fear of hypoglycemia is a salient barrier to exercise in individuals with T1D [7,9]. Hypoglycemia is a common occurrence in response to exercise in individuals with T1D, and it can be difficult to predict, avoid, and manage. Studies have shown that the frequency of hypoglycemia outside the context of exercise ranges from 42 to 91 events per person-year in adults with T1D, with ∼12% of individuals having at least 1 episode of severe hypoglycemia per year [36,37]. Data regarding the prevalence of exercise-induced hypoglycemia in T1D are limited largely to laboratory-based studies, which have varied depending on the nature of exercise and treatment strategies employed [38], although no single exercise modality or treatment strategy is fully protective. The finding that individuals with IR reported glycemic factors, specifically hypoglycemia, as more salient barriers to exercise than individuals without IR could be related to the greater exposure to exercise-induced dysglycemia given that exercise participation levels were, on average, lower in those with IR. However, the association between glycemia-related barriers to exercise and eGDR remained robust after adjustment for exercise participation levels. Importantly, the association between eGDR and subscales of the BAPAD-1 scale suggests that this tool captures general aspects related to T1D, and it is therefore possible that individuals able to navigate exercise barriers are also better equipped to manage weight, diabetes control, and blood pressure. Although individuals without IR outlined nonglycemic factors, specifically fitness and physical health status, as salient barriers to exercise compared with individuals with IR, this could be related to the stabilization of their blood glucose levels. Notably, moderate exercise participation levels were, on average, higher in individuals without IR.

In this study, we did not observe differences in QoL between individuals with T1D stratified by IR status. It has been consistently shown that QoL is lower in people with T1D compared to people without T1D, and that the presense of IR also lowers QoL in the general population [10,11,13,39]. As such, it was unexpected that IR in T1D was not associated with further decrements in QoL. This may have been due to the relatively conservative sample size [40]. Importantly, when comparing the QoL data normalized to a general population with the present T1D data, the overall physical health domain and mental health domain values for SF-36 were lower than those reported for the general population [41,42]. Furthermore, our data show that individuals with T1D with IR had lower QoL scores in each domain when compared with individuals with IR in another study [43]. The association between the emotional problems subscale and eGDR became significant after sequential adjustment, which warrants further study, particularly as this is at odds with the other subscales.

In addition to being the first investigation on the effects of IR on barriers to exercise in T1D, our study has a number of notable strengths. First, we employed validated questionnaires to assess attitudes toward exercise and QoL. Second, sampling came from a relatively broad and representative population of individuals with T1D, although our population excluded individuals with established diabetes complications. Third, we utilized eGDR—a robust and validated surrogate measure of IR that has previously been shown to be a strong predictor of both diabetes complications and mortality [27]; nevertheless, we acknowledge that our assessment of IR was indirect. Thus, our individuals with T1D with IR represent a high-risk subpopulation in need of a targeted intervention.

Our study also has some limitations. Given the cross-sectional design of our study, it is not possible to infer causation from our findings. Although it is possible that the lower exercise participation level may be a contributing factor to the development of IR, it is also likely that the presence of IR impacts exercise participation. We did not assess our participants' understanding of IR, so our anecdotal oberservations show that this is generally poorly understood within the context of T1D and rarely discussed in routine diabetes practice. Our participants were not informed of their IR status before completion of the questionnaires. As such, we spectualte that it is unlikely that awareness of IR influenced the questionnaire responses. From our reporting methods, it was not possible to objectively assess exercise participation levels, and therefore our findings were based on self-report data. Last, we used pooled data from 2 previous RCTs and thus we cannot exclude the potential for selection bias; therefore, real-world studies are needed using larger cohorts and involving different ethnic groups to ensure generalizability of our findings.

In conclusion, individuals with T1D and IR exercise less frequently and have greater perceived barriers to exercise than individuals with T1D without IR. Risk of hypoglycemia was the greatest barrier to exercise in individuals with T1D with IR, yet non–diabetes-related barriers to exercise were found to be more salient in individuals with T1D without IR. Nevertheless, there was no effect seen on the SF-36 QoL domains between IR groups. As such, individually centred physical activity interventions should be designed that consider and account for differences in exercise attitudes in the specific subpopulations of individuals with T1D.

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Author Disclosures

Conflicts of interest: None.

Author Contributions

A.M.A. performed the statistical analysis and data searches, contributed to the selection of the references and was involved in manuscript creation. M.H., M.A.Z., R.A.A., and J.B. critically appraised the work and were involved in editing of the final manuscript. M.D.C. collected the data, performed searches, contributed to selection of references, was involved in editing the final manuscript, and had general oversight of the work. All authors reviewed and approved the final manuscript submitted for publication.

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