A Multidisciplinary Evaluation of a Virtually Supervised Home-Based High-Intensity Interval Training Intervention in People With Type 1 Diabetes

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OBJECTIVE

Adopt a multidisciplinary approach to evaluate a virtually supervised home-based high-intensity interval training (Home-HIT) intervention in people with type 1 diabetes.

RESEARCH DESIGN AND METHODS

Eleven individuals with type 1 diabetes (seven women; age 30 ± 3 years; $\dot{V}O_{2peak}$ 2.5 ± 0.2 L/min; duration of diabetes 10 ± 2 years) completed 6 weeks of Home-HIT. A heart rate monitor and mobile phone application were used to provide feedback to the participants and research team on exercise intensity (compliance) and adherence.

RESULTS

Training adherence was 95 ± 2%, and compliance was 99 ± 1%. Home-HIT increased $\dot{V}O_{2peak}$ by 7% ($P = 0.017$) and decreased insulin dose by 13% ($P = 0.012$). Blood glucose concentration did not change from baseline to immediately or 1 h post Home-HIT. Qualitative perceptions of Home-HIT and the virtual-monitoring system were positive, supporting that the intervention successfully removed exercise barriers in people with type 1 diabetes.

CONCLUSIONS

Virtually monitored Home-HIT resulted in high adherence alongside increased $\dot{V}O_{2peak}$ and decreased insulin dose.

Many people with type 1 diabetes lead a sedentary lifestyle (1–3), with lack of time and fear of hypoglycemia identified as key exercise barriers (4,5). High-intensity interval training (HIT) may address these barriers, with studies showing that HIT improves cardiorespiratory fitness and vascular function without the reductions in glycemia associated with moderate-intensity continuous training (MICT) (6). However, during these studies (6,7), HIT was performed under laboratory conditions with strict researcher supervision, meaning the "real-world" potential of HIT is unclear for people with type 1 diabetes. The HIT protocol used a cycle ergometer, introducing additional exercise barriers, such as difficulty accessing equipment or facilities (including distance and cost), and potential embarrassment due to negative body image if performed within a gym (4,5). This study used a multidisciplinary approach to

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NOVEL COMMUNICATIONS IN DIABETES

evaluate a novel, virtually monitored home-based HIT (Home-HIT) intervention in people with type 1 diabetes.

RESEARCH DESIGN AND METHODS

Eleven individuals with type 1 diabetes (seven women; age 30 ± 3 years; $\dot{V}O_{2peak}$ 2.5 ± 0.2 L/min; duration of diabetes 10 ± 2 years; HbA_{1c} 8.0 ± 0.6% [64 ± 7 mmol/mol]; BMI 27.3 ± 1.6 kg/m^2; daily insulin dose 0.31 ± 0.06 IU/kg/day) completed 6 weeks of Home-HIT. The Home-HIT program was completed in an unsupervised place of the participant's choosing. Participants performed repeated 1-min bouts of high-intensity exercise interspersed with 1-min of rest. During the intervals they were asked to achieve a heart rate (HR) of ≥80% of their predicted maximum (220 − age). Intervals were composed of two 30-s simple bodyweight exercises (e.g., star jumps then burpees) with no rest in between. Participants were provided with 18 exercises with 9 suggested exercise pairs, detailed in an information pack, and participants were free to choose exercises according to personal preference. Participants were advised to train 3×/week, and complete 6 1-min intervals per session in weeks 1–2, increasing to 8 in weeks 3–4 and 10 in weeks 5–6. Participants were virtually monitored using a HR monitor that connected via Bluetooth to their smartphone (Polar Beat; www.polar.com/beat/uk-en). Although participants were monitored virtually, training was completed without researcher supervision or encouragement. This allowed participants to monitor their HR and provided immediate feedback on exercise intensity. Following each session, HR data were automatically uploaded to a cloud storage site (www.flow.polar.com), which allowed participants to monitor their progression. The website was also available to the research team to monitor whether the program was being completed as advised. The research team used these data to contact participants by text/email every 2 weeks to inquire about training progress and to provide support if required. If participants missed consecutive sessions, messages inquired as to whether there was a specific reason. The monitoring system provided an objective measure of adherence (number of sessions completed) and compliance (whether HR thresholds and correct number of intervals were achieved during each session) (Supplementary Fig. 1).

Throughout the program, participants were asked to only exercise if their blood glucose levels were 7–14 mmol/L, in accordance with Exercising for Type 1 Diabetes (EXTOD) guidelines (8). They were also asked to record their blood glucose pre, post, and 1 h post each session and whether they used additional carbohydrates or insulin during or following each session.

$\dot{V}O_{2peak}$ was measured during pre- and posttesting, which took place ~72 h before the first training session and 72 after the final training session, respectively. During posttesting, participants completed an anonymous online qualitative survey (www.surveymonkey.co.uk) to explore barriers and facilitators to exercise before the intervention and their experiences of Home-HIT (Supplementary Table 1). During the first and final 7 days of the program, participants monitored their insulin dose and blood glucose using an 8-point profile: before and 2 h after each meal, just before bed, and at 2:00 A.M.

The study was approved by the Black Country National Health Service Research Ethics Committee (West Midlands, U.K.), and written informed consent was obtained from all individuals prior to participation.

Statistical Analysis

Owing to the small sample size, data were assessed using the nonparametric Wilcoxon signed rank test, except for change in blood glucose concentration pre, post, and 1 h postexercise, which was assessed with a Friedman test, with the within-group factor exercise (pre vs. post, vs. 1 h post), using IBM SPSS Statistics for Windows. Significance was set at $P \leq 0.05$, and data are presented as mean ± SEM. The qualitative survey responses were analyzed using a framework approach (9).

RESULTS

Training adherence was 95 ± 2% (range 83–100%), with participants completing the advised number of intervals at the 80% HR_{max} target in 99 ± 1% of sessions (range 94–100%). Blood glucose remained stable during and after exercise, with the mean blood glucose concentration immediately postexercise and 1 h postexercise being not different from baseline ($P = 0.249$) (Supplementary Fig. 2). Carbohydrate was consumed to prevent hypoglycemia in 6 ± 3% sessions (10 of 188 sessions), and insulin was needed for hyperglycemia after 2 ± 1% of sessions (3 of 188 sessions). No severe hypoglycemic episodes requiring third-party intervention were reported.

Six weeks of Home-HIT increased $\dot{V}O_{2peak}$ by 7% ($P = 0.017$), and there was a 13% decrease in daily short-acting insulin ($P = 0.012$) (Supplementary Fig. 2). There was no change in mean blood glucose concentration (pre 8.8 ± 0.5 mmol/L; post 8.6 ± 0.4 mmol/L; $P = 0.445$), measured using a 7-day 8-point diary, and no change in BMI (pre 27.3 ± 1.6 kg/m^2; post 27.4 ± 1.6 kg/m^2; $P = 0.646$).

Three key themes and subthemes were developed from the survey responses: *1*) flexibility of Home-HIT with the subthemes type 1 and nontype 1 diabetes–related flexibility, *2*) motivation with the subthemes Home-HIT and virtual monitoring, and *3*) the "HIT" experience. Table 1 shows the frequency of participants' positive and negative responses relating to each theme. The top three exercise barriers reported were lack of time (91%), fear of hypoglycemia (27%), and lack of motivation (18%). Supplementary Table 2 shows detailed information on participants' past exercise experiences, current activity level, feelings toward their current activity level, and exercise barriers before the intervention.

CONCLUSIONS

We demonstrate that people with type 1 diabetes are able to engage and adhere to a virtually monitored Home-HIT program and that this is safe and effective. Home-HIT increases $\dot{V}O_{2peak}$ and reduces insulin dose, while appearing to reduce traditional exercise barriers as well as fear of hypoglycemia, with 95% adherence rates. Training diaries showed that blood glucose remained stable up to 1 h following Home-HIT sessions (Supplementary Fig. 2*C*), supporting previous laboratory-based research (6). This contrasts with moderate-intensity continuous training, where there is a consistent drop in glycemia in people with type 1 diabetes (6,10–12). The blood glucose data were supported by the survey responses suggesting participants felt comfortable doing Home-HIT because their

Table 1—Summary of participant responses in qualitative survey

Theme	Subtheme	Positive responses	Negative responses
Flexibility of Home-HIT	Type 1 diabetes–related flexibility	Reducing occurrence of hypoglycemia (F, H) Improved blood glucose control (E)	Unpredictable blood glucose (I)
	"The even blood glucose levels are an absolute dream come true for exercise with T1. I'd even try it of an evening and go to bed less worried." (Participant F)		
	Nontype 1 diabetes–related flexibility	Being able to exercise at home (C, D, E, H) Time efficient (C, E, J, G, H, I) Free (A, D, E, J) No equipment (E)	Still difficult to find time to fit exercises in (A, E, C) Too many interruptions at home (B, D) Space to do the exercises (A, D, H)
	"It was very easy to fit the workout sessions into my day, depending on what I was doing due (to) the time it took to complete." (Participant H)		
Motivation	Home-HIT	Improved my body composition (D) Felt better after session (E, C) Improved my fitness (G, H, I, K) Progression of the intervention (E)	Motivation to do the exercises (D, E, F, G, I, J) The exercise was demanding (I, J)
	"I liked the opportunity to choose which exercises to do during each session, and how throughout the programme the intensity increased and this became a challenge." (Participant E)		
	Virtual monitoring	Heart rate monitoring to see progression (C, E) Being monitored remotely improved my motivation (E, A) Immediate feedback from HR monitor (C)	
	"I would consider doing HIT at home if I could view my progress through a monitor device like a HR monitor." (Participant E)		
"HIT" experience		Having a program to follow (A, J) Lack of boredom (D) Choice of exercises (E) Progression of intervention (E)	Timing the intervals (C, G) Monitoring the form of the exercises (C) More variety of exercises required (F, H)
	"I liked the interval training as you do not get a chance to become bored if you have a set training programme to follow." (Participant D)		

Letters indicate participants who gave responses related to each theme. Representative participant quotes are placed below each theme and subtheme. T1, type 1 diabetes.

blood glucose concentrations remained stable.

Home-HIT sessions lasted 12–20 min, meaning the weekly time commitment was at least 90 min less than the recommended 150 min (13). Many participants reported time efficiency of Home-HIT as a major advantage in the survey and appreciated the convenience of not having to travel, which added to the time efficiency. Furthermore, participants liked being able to exercise at home because there was more privacy and the program was free and required no equipment.

Lack of motivation is a common barrier to achieving physical activity targets (4). The survey responses suggest the design of our Home-HIT intervention contributed to improving motivation to exercise. These motivating factors included the range of exercises available and the progression in number of intervals. Participants suggested that the virtual monitoring contributed to their motivation, as it provided instant feedback on exercise intensity and allowed progression to be tracked by exercise professionals who could provide feedback. This feedback probably contributed to the high adherence. HR monitoring is the most accurate way to track the body's response to activity, providing objective, personalized data that account for age and fitness (14), reflecting exercise intensity regardless of exercise type (14). Such monitoring systems may provide a relatively inexpensive (~£40 per HR monitor and mobile application) strategy to engage with participants and improve uptake, adherence, compliance, and ultimately, health outcomes.

We decided not to include an untrained control group. Although this would have strengthened the design, it would have reduced the feasibility of completing the study. Our primary aim was to assess safety and acceptability of virtually monitored Home-HIT in people with type 1 diabetes, which would not have benefited from an untrained control group. Secondly, time of day that training was undertaken was not controlled, and recent work has shown that time of day influences glycemic response to exercise in people with type 2 diabetes (15). However, participants were free to complete Home-HIT at any time of day, suggesting a flexible training intervention that can be used in the "real world." Furthermore, participants stated in the survey that they felt no increased risk of hypoglycemia even when exercising in the evening (Table 1). Future research should use continuous glucose monitoring to investigate how time of day influences the effects of Home-HIT on glycemia and efficacy.

Our study suggests virtually monitored Home-HIT is a safe, effective, and acceptable strategy for supporting people with type 1 diabetes to exercise.

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