A MULTI-DISCIPLINARY EVALUATION OF A VIRTUALLY-SUPERVISED HOME-BASED HIGH-INTENSITY INTERVAL TRAINING INTERVENTION IN PEOPLE WITH TYPE 1 DIABETES

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SHORT TITLE: **HOME-HIT IN TYPE 1 DIABETES**

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Abbreviations:

HIT – High-intensity interval training

Home-HIT - Home-based high-intensity interval training

HR - Heart rate

MICT – Moderate-intensity continuous training

$\dot{V}O_{2peak}$ – Peak oxygen consumption

EXTOD – Exercising with type 1 diabetes

ABSTRACT

OBJECTIVE: Adopt a multi-disciplinary 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 (7 women; age 30±3 years; $\dot{V}O_{2peak}$ 2.5±0.2 L/min^{-1}; duration of diabetes 10±2 years) completed six weeks of Home-HIT. A HR 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 1h 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.

INTRODUCTION

Many people with type 1 diabetes lead a sedentary lifestyle (1–3), with lack of time and fear of hypoglycaemia 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 glycaemia 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 multi-disciplinary approach to 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 (7 women; age 30±3 years; $\dot{V}O_{2peak}$ 2.5±0.2 L/min^{-1}; 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/d^{-1}) completed six weeks of Home-HIT. The Home-HIT programme was completed in an unsupervised place of the participant's choosing. Participants performed repeated 1-minute bouts of high-intensity exercise interspersed with 1-minute of rest. During the intervals they were asked to achieve a HR of ≥80% of their predicted maximum (220–age). Intervals were composed of two 30-second 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 (Supplemental Material). Participants were advised to train 3x/week, and complete six 1-minute 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 which 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 if the programme was being completed as advised. The research team used this data to contact participants by text/email every 2 weeks to enquire about training progress and to provide support if required. If participants missed consecutive sessions, messages enquired 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 Figure 1).

Throughout the programme 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 1h 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 post-testing, which took place approximately 72h before the first training session and 72 after the final training session, respectively. During post-testing, 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 programme, participants monitored their insulin dose and blood glucose using an 8-point profile: before and 2h after each meal, just before bed, and at 2am.

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

Statistical Analysis

Due to the small sample size, data were assessed using the non-parametric Wilcoxon Signed-Rank Test, except for change in blood glucose concentration pre, post and 1h post-exercise which was assessed with a Friedman Test, with the within group factor exercise (pre vs. post, vs 1h 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 analysed 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 post exercise and 1h post exercise being not different from baseline (P=0.249; Supplementary Figure 2). Carbohydrate was consumed to prevent hypoglycaemia in 6±3% sessions (10/188 sessions), and insulin was needed for hyperglycaemia after 2±1% of sessions (3/188 sessions). No severe hypoglycaemic 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 Figure 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 seven day 8-point diary and no change in BMI (pre=27.3±1.6 $kg \cdot m^{-2}$; post=27.4±1.6 $kg \cdot m^{-2}$; *P*=0.646).

Three key themes, and sub-themes, were developed from the survey responses; 1) *Flexibility of Home-HIT* with the sub-themes *type 1* and *non-type 1 diabetes related flexibility*, 2) *Motivation* with the sub-themes *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 3 exercise barriers reported were lack of time (91%), fear of hypoglycaemia (27%) and lack of motivation (18%). Supplementary Table 2 shows detailed information on participants' past exercise experiences, current activity level, feelings towards 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 programme, 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 hypoglycaemia, with 95% adherence rates. Training diaries showed that blood glucose remained stable up to 1h following Home-HIT sessions (Supplementary Figure 2C), supporting previous laboratory-based research (6). This contrasts with MICT, where there is a consistent drop in glycaemia 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 blood glucose concentrations remained stable.

Home-HIT sessions lasted 12-20 minutes, meaning weekly time-commitment was at least 90 minutes less than the recommended 150 minutes (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, the programme 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 personalised data that accounts 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 glycaemic 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 hypoglycaemia 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 glycaemia 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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REFERENCES

1. Matson RIB, Leary SD, Cooper AR, Thompson C, Narendran P, Andrews RC. Objective Measurement of Physical Activity in Adults With Newly Diagnosed Type 1 Diabetes and Healthy Individuals. Front Public Health. 2018;6:360.

2. Tielemans SM a. J, Soedamah-Muthu SS, De Neve M, Toeller M, Chaturvedi N, Fuller JH, et al. Association of physical activity with all-cause mortality and incident and prevalent cardiovascular disease among patients with type 1 diabetes: the EURODIAB Prospective Complications Study. Diabetologia. 2013 Jan;56(1):82–91.

3. Makura CB, Nirantharakumar K, Girling AJ, Saravanan P, Narendran P. Effects of physical activity on the development and progression of microvascular complications in type 1 diabetes: retrospective analysis of the DCCT study. BMC Endocr Disord. 2013 Oct 2;13:37.

4. Lascar N, Kennedy A, Hancock B, Jenkins D, Andrews RC, Greenfield S, et al. Attitudes and Barriers to Exercise in Adults with Type 1 Diabetes (T1DM) and How Best to Address Them: A Qualitative Study. Petersen I, editor. PLoS ONE. 2014 Sep 19;9(9):e108019.

5. Brazeau A-S, Rabasa-Lhoret R, Strychar I, Mircescu H. Barriers to physical activity among patients with type 1 diabetes. Diabetes Care. 2008 Nov;31(11):2108–9.

6. Scott SN, Cocks M, Andrews RC, Narendran P, Purewal TS, Cuthbertson DJ, et al. High-Intensity Interval Training Improves Aerobic Capacity Without a Detrimental Decline in Blood Glucose in People With Type 1 Diabetes. J Clin Endocrinol Metab. 2019 Feb 1;104(2):604–12.

7. Scott SN, Cocks M, Andrews RC, Narendran P, Purewal TS, Cuthbertson DJ, et al. Fasted High-Intensity Interval and Moderate-Intensity Exercise Do Not Lead to Detrimental 24-Hour Blood Glucose Profiles. J Clin Endocrinol Metab. 2019 Jan 1;104(1):111–7.

8. Narendran P, Jackson N, Daley A, Thompson D, Stokes K, Greenfield S, et al. Exercise to preserve β-cell function in recent-onset Type 1 diabetes mellitus (EXTOD) - a randomized controlled pilot trial. Diabet Med. 2017;34(11):1521–31.

9. Ritchie J, Spencer L. Chapter 9: Qualitative data analysis for applied policy research. In: Burgess RG, Bryman A, editors. Analyzing qualitative data [Internet]. London ; New York: Routledge; 1994 [cited 2019 Feb 14]. p. 173–94. Available from: http://ezproxy.library.uq.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=nlebk&AN=72371&site=ehost-live

10. McMahon SK, Ferreira LD, Ratnam N, Davey RJ, Youngs LM, Davis EA, et al. Glucose requirements to maintain euglycemia after moderate-intensity afternoon exercise in adolescents with type 1 diabetes are increased in a biphasic manner. J Clin Endocrinol Metab. 2007 Mar;92(3):963–8.

11. García-García F, Kumareswaran K, Hovorka R, Hernando ME. Quantifying the Acute Changes in Glucose with Exercise in Type 1 Diabetes: A Systematic Review and Meta-Analysis. Sports Medicine. 2015 Apr;45(4):587–99.

12. Davey RJ, Howe W, Paramalingam N, Ferreira LD, Davis EA, Fournier PA, et al. The effect of midday moderate-intensity exercise on postexercise hypoglycemia risk in individuals with type 1 diabetes. J Clin Endocrinol Metab. 2013 Jul;98(7):2908–14.

13. Colberg SR, Sigal RJ, Yardley JE, Riddell MC, Dunstan DW, Dempsey PC, et al. Physical Activity/Exercise and Diabetes: A Position Statement of the American Diabetes Association. Diabetes Care. 2016;39(11):2065–79.

14. Zisko N, Skjerve KN, Tari AR, Sandbakk SB, Wisløff U, Nes BM, et al. Personal Activity Intelligence (PAI), Sedentary Behavior and Cardiovascular Risk Factor Clustering - the HUNT Study. Prog Cardiovasc Dis. 2017 Jul;60(1):89–95.

15. Savikj M, Gabriel BM, Alm PS, Smith J, Caidahl K, Bjornholm M, et al. Afternoon exercise is more efficacious than morning exercise at improving blood glucose levels in individuals with type 2 diabetes: a randomised crossover trial. Diabetologia. 2019 Feb; 62(2): 233-237.

Table 1. Summary of participant responses in qualitative survey

Letters indicate participants that gave responses related to each theme. Representative participant quotes are placed below each theme and sub-theme.

Theme	Sub-theme	Positive Responses	Negative Responses
Flexibility of Home-HIT	Type 1 diabetes related flexibility	Reducing occurrence of hypoglycaemia (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)		
	Non-type 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 heart rate 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 programme 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)		