Kliszczewicz B, Buresh R, & Ray HE. Feasibility of Minimal Dose High Intensity Body-weight Circuit Training in Individuals With Type 2 Diabetes: A Pilot Study. J Sport Human Perf 2021; 9(2):22-32.

DOI: https://doi.org/10.12922/jshp.v9i2.173

JOURNAL OF SPORT AND HUMAN PERFORMANCE

ORIGINAL RESEARCH **OPEN ACCESS**

FEASIBILITY OF MINIMAL DOSE HIGH INTENSITY BODY-WEIGHT CIRCUIT TRAINING IN INDIVIDUALS WITH TYPE 2 DIABETES: A PILOT STUDY

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ABSTRACT

Background: The use of body-weight resistance exercise and a minimal time duration requirement can be combined to form a high intensity body-weight circuit training program (HIBC), and may be a feasible and attractive option for those with Type 2 Diabetes Mellitus (T2DM). The purpose of this pilot was to evaluate the effectiveness of an minimal time commitment HIBC intervention on metabolic biomarkers, body composition, and fitness. **Methods:** Three females (55±4yrs) and two males (64±1yrs) with T2DM underwent assessments of glycosylated hemoglobin (HbA1c) and fasting glucose (FG), and lipids. Body composition via dual-energy x-ray absorptiometry, aerobic fitness (submaximal treadmill test), blood pressure (SBP/DBP), and resting heart rate (RHR) were assessed. Participants completed 16-weeks of HIBC. All assessments were repeated upon completion. **Results:** No differences were observed in the following variables; Body composition: Pre and Post changes in mean weight 2.2 ± 2.8 (p=0.31), body fat% -0.1 ± 1.1% (p=1.0), lean mass 1.2 ± 1.22 kg (p=0.13). Aerobic fitness: estimated VO2max 2.26 ± 4.5 ml/kg/min (p=0.63), SBP -6.4 ± 12.5mmhg (p=0.38), DBP -1.4 ± 3.5mmhg (p=0.50), RHR -1.8 ± 4.7bpm (p=0.50). Metabolic biomarkers: FG -14.9 ± 33.4 mg/dL (p=0.44), HDL 1.4 ± 4.2 mg/dL (p=0.63), LDL -4.0 ± 12.6 mg/dL (p=0.63), HbA1c -0.3 ± .28% (p=0.25). **Conclusions:** Though the main findings of this study were not statistically significant, but the physiological responses could be clinically meaningful in that improvements in metabolic profiles were similar in magnitude to both aerobic and resistance training interventions.

Keywords: Metabolism, Exercise, Intervention

INTRODUCTION

Exercise is a well-known therapeutic intervention for the treatment of Type 2 Diabetes Mellitus (T2DM), with several different modalities examined over recent years (3, 10, 22). Current exercise guidelines for those diagnosed with T2DM include accumulating 150-minutes of moderate intensity aerobic exercise each week (10). Given that lack of time is one of the commonly reported barriers to exercise (23, 24), the implementation of high-intensity interval training (HIT) interventions shows promise for T2DM management (17, 25, 30, 35) and greatly reduces time requirements. However, HIT interventions are generally single modality (i.e. cycling or running), do not incorporate full body muscle recruitment, and cause discomfort related to vigorous exercise intensity (16, 29). Furthermore, commonly prescribed resistance training programs that do incorporate full-body muscle recruitment impose a time requirement similar to sustained aerobic exercise training programs (9, 10), necessitate access to specialized equipment, and may require complicated and relatively risky movements (e.g. free weights). Combined, time commitments, vigorous intensity, and complicated exercise movements, may prove to be intimidating to people who are unfamiliar with exercise.

Within the fitness industry, a variety of high-intensity exercise training programs (e.g. Orange Theory®, CrossFit®, High-intensity Functional Training [HIFT]) have demonstrated some success in mobilizing previously sedentary individuals (38-40). These programs are typically comprised of functional movements such as aerobics (e.g., running, rowing, swimming, etc.), calisthenics (e.g., push-ups, pull-ups, sit-ups, etc.) and weight lifting (e.g., clean, snatch, deadlift, etc.), performed at high intensities, with a goal of improving general fitness and performance (13). Adherence to many variations of these high-intensity exercise approaches appears to be based in part on the appeal of short exercise duration, creating "more tolerable" sessions. Because of the popularity of these types of fitness programs, clinical applications should be explored, including among those with T2DM. Recently, HIFT, has been utilized in participants with T2DM (12, 28). According to these studies, improvements in beta-cell function, insulin sensitivity, and body composition were observed; however, participants realized no changes in fasting glucose, or lean mass (12, 28). These results suggest that HIFT interventions are a promising approach to diabetes management, but they still require the use of expensive facility memberships, equipment, and supervision. A practical application of these programs would utilize general concepts (e.g., repetition scheme, duration, intensity…etc.), while removing free weights and technical movements that may be too difficult or daunting for clinical and/or aged populations. To this effect, the use of body-weight resistance and minimal duration requirement can be combined to produce a high intensity body-weight circuit training program (HIBC), and may prove to be a feasible and attractive option for those with T2DM.

The proposed 16-week HIBC intervention will greatly reduce the time commitment (i.e., 15-40 minutes per week) and employ relatively simple full body exercises appropriate for nearly all ages and experience levels (modified squats, rows, push-ups and crunches), which have been shown to cause skeletal muscle adaptations and improvements in aerobic fitness and metabolic profiles. An additional advantage of the HIBC intervention is its progressive nature, in which, over time volume slowly increases, allowing for a gradual progression that appears to also be supportive of exercise adherence and continued adaptation (15). Therefore, the purpose of this pilot was to evaluate the effectiveness of an HIBC intervention on metabolic biomarkers, body composition, and fitness.

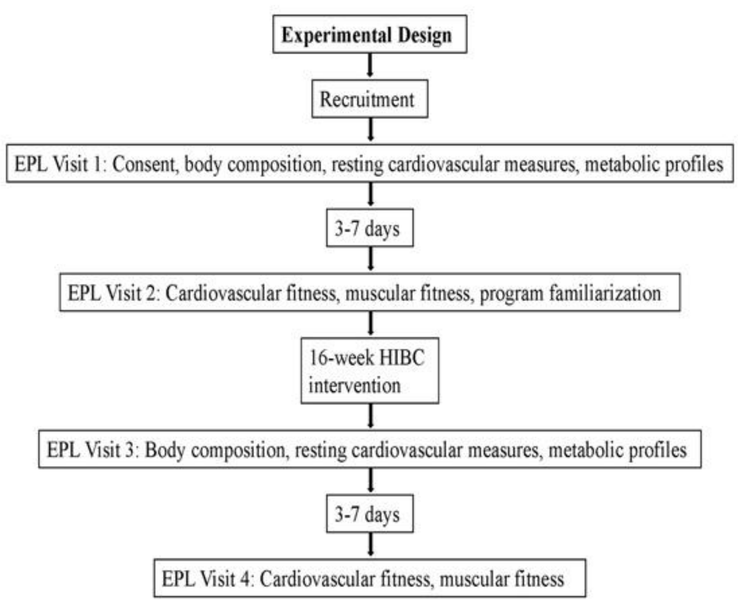
METHODS

Prior to the collection of any data, University Institutional Review Board approved all testing procedures and protocols, and all experiments were performed in accordance with relevant guidelines and regulations. Additionally, this research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (27). Nine total participants were recruited and volunteered for this study. Each individual was made aware of the procedures and potential risks associated with the study and signed an informed consent prior to participation. Inclusion criteria require participants have been diagnosed with type 2 diabetes for at least one year, must not be taking exogenous insulin, and must have a hemoglobin A1c level between 6.5% and 10%. Participants were not currently engaged in a regimented exercise program, which was defined as not having participated in at least 30 minutes of moderate intensity physical activity (40-59% VO_2R) on at least 3 days of the week for at least 3 months. Participants also filled out a health history questionnaire and any individual who reported having orthopedic conditions, or cardiovascular, or pulmonary disease were excluded from the study. Following obtaining informed consent, participants received clearance from their overseeing physician.

Experimental design

Participants reported to the University's Exercise Physiology Lab (EPL) on four separate occasions. Visits one and two occurred prior to the intervention and were separated by three to seven days, while visits three and four occurred following the 16-week intervention and were also separated by three to seven days. All visits occurred between 8:00 am and 10:00 am in a fasted condition (no medication as physician approved, and no food or beverage except water for 12 hours), no physical activity for 24 hours, or caffeine for 12 hours. Visits one and three were designated to collected body composition, resting cardiovascular measures, and metabolic profiles. Visits two and four were designated to collect markers of cardiovascular fitness (See Figure 1).

Figure 1.



Measurements

Body composition- Height, weight, were assessed using a Tanita Scale (Tanita Corporation of America, Arlington Heights, IL). Participants underwent a dual energy x-ray absorptiometry (DEXA) scan (General Electric, Inc., Waukesha, WI) in order to determine body fat percentage (BF%), lean mass (LM), and fat mass (FM).

Cardiovascular Markers- Resting heart rate (RHR) and blood pressure (systolic [SBP] and diastolic [DBP]) were measured in duplicate, while in a seated position using an automated digital blood pressure monitor (Omron, Novi, MI), and the average of the two readings was recorded.

Metabolic Markers- In order to assess metabolic profiles finger-stick blood samples were collected by a phlebotomy trained investigator to allow for the measurement of hemoglobin A1c (HbA1c) (Siemans DCA Vantage, Malvern, PA), fasting blood glucose (FBG) was measured in duplicate (Medtronic Contour Next, Bayer, Pittsburgh, PA), lipid profile; low density lipoprotein (LDL), high density lipoprotein (HDL), total cholesterol (Total C), and Triglycerides (TG) (Alere Cholestech LDX, Orlando, FL) Following the initial fasting finger stick, participants underwent a 2-hour oral glucose tolerance test (OGTT). This assessment begins following the fasting finger-stick blood sample collection. Participants consumed a beverage containing 75 g of glucose, and then rested quietly for 2 hours. Additional finger-stick blood samples were collected 1 hour and 2 hours after the beverage is consumed to allow assessment of glucose levels as per standard OGTT (2, 21). Following the completion of the OGTT, participants were permitted to take their prescription medication and consume a breakfast of their choosing.

Aerobic Fitness- A sub-maximal modified Bruce protocol exercise test beginning at a 1.7 mph and 0% grade, and increasing speed and/or grade every three minutes, was used to estimate aerobic fitness (5, 14). Exercise continued until participant achieved 85% of age-predicted maximal heart rate (207 – [0.7 x age]) (5, 14). At that time, speed and grade were reduced to allow participant to cool down.

HIBC Intervention

Upon completing the lab sessions, participants were familiarized with the at-home HIBC intervention. Due to the nature of the population, range of motion was limited in some participants and therefore exercise was modified to a level of personal ability and comfort. Although range of motion may not be optimal, several studies have demonstrated that exercise intervention in those with physical limitations (e.g. arthritis, orthopedic issues.) still result in improvements in markers of health (7, 11). Therefore, the program involved the use of both bodyweight and suspension training equipment (TRX® Fit System) with modified movements. The TRX® system was used to modify squats and rows while attached to the top of a door frame. The modified movements are as follows: (Figure 2. A-D). *Modified Squats (A)*: participants were instructed to hold the handles of the straps with arms extended (until the straps were taut), participants then leaned back in a standing position and performed a squat within a comfortable range of motion while weight is being distributed to the band. *Modified Rows (B)*: Similar to the squat, participants were instructed to grab the handles with arms and legs extended. They were then instructed to find a comfortable angle by which to perform a "row" (pulling the handles to the rib cage) with arms at a 45-degree angle. *Modified Push-Ups (C)*: participants then performed push-ups on their knees with a flat back and hands underneath their shoulders.

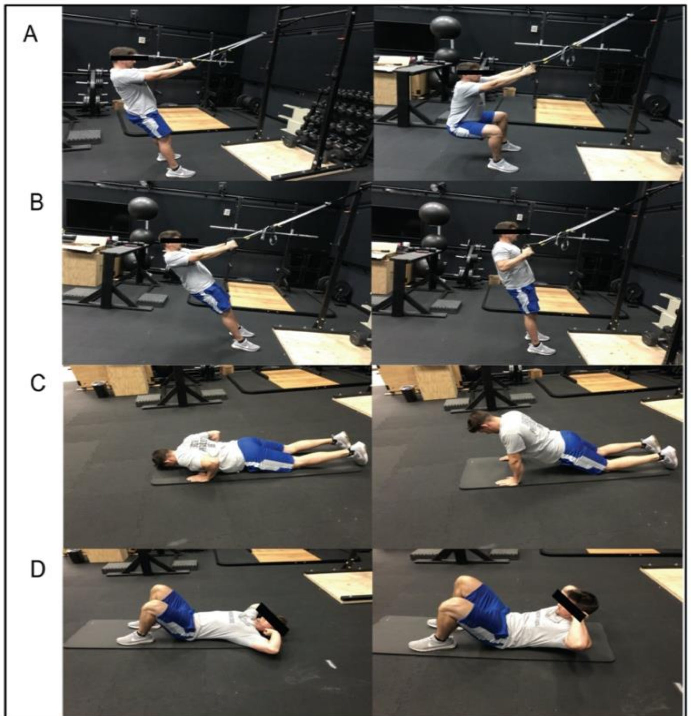


Figure 2. Modified exercises to be used in the HIBC Intervention: (**A**) modified squats, (**B**) modified rows, (**C**) modified push-ups, (**D**) modified crunches.

They were instructed to lower their chest towards the ground in a controlled manner and as far as comfort allowed them. *Crunches (D)*: participants laid on their backs with feet flat on the floor, approximately 8-10 inches from their buttocks, hands in a position to prevent the supporting of the neck and asked to lift their shoulders slightly off the ground. The objective of the bout was to compl ete as many of these cycles (Figure 2. A-D) as quickly as possible while maintaining proper form for the allotted time (e.g. 5-minutes). Importantly, once participants are familiar with the movements, they were instructed to perform them in a similar manner throughout the duration of the study. Participants were also instructed to increase the intensity of exercise by increasing the rate at which the movements are performed rather than changing body position to increase resistance.

HIBC Exercise Protocol- prior to the HIBC bouts participants were instructed to perform a light, 5-minute warm-up on a treadmill, stationary cycle if available, or a brisk walk in their homes. The HIBC circuit repetition and order is as follows: modified squats (10 repetitions), modified rows (5 repetitions), crunches (10 repetitions), and modified push-ups (5 repetitions). The exercise sessions involved repeating a series of repetitions of each movement in sequence, and completing as many sequences as possible in good form in the time allotted for the exercise (initially, 5 minutes). Participants were instructed to complete three sessions per week and documented the number of cycles completed. After 3 weeks of consistent training, participants were asked to add a 4th session each week as tolerated. Initially, the HIBC sessions were 5 minutes long, and the duration of the sessions were increased by one minute each week as tolerated beginning in week four, peaking at 10-minutes per session as early as the eighth week of training. Session duration was capped at 10 minutes. Participants were requested to not change their dietary habits throughout the intervention.

Statistics

The Wilcoxon Ranked Sum test (RST) (43) is a nonparametric procedure that is preferred when there is a small sample size and paired difference in the measurements does not appear to follow a normal distribution. SAS version 9.4 was used for all computations. Alpha was set to ($p<0.05$).

RESULTS

Nine total participants volunteered for this study, none of which were excluded from participation. Three participants dropped out of the study due to illness (n = 1) or life events (n= 2), while 1 was excluded from analysis due to recent need for exogenous insulin. A total of three females (55 ± 4yrs) and two males (64 ± 1yrs) completed the study and were included in analysis. Self-reported adherence (percent of completed sessions) was 92.6 ± 8.8%. Table 1 reports the pre and post means of the measurements with the standard deviation of each outcome of interest, and cohens d effect sizes. The table also reports the Wilcoxon Signed Rank test statistic and corresponding p-value for each outcome. Individual results can be seen in figures 3-6. No participants reported taking any medications prior to testing for pre or post measurements.

Table 1. Outcome Measures

Participant Characteristics

N=5	BW (kg)	BF (%)	FM (kg)	LM (kg)	VO_{2max} (ml/kg/min)	RHR (bpm)	SBP (mm/hg)	DBP (mm/hg)
PRE	98.1 ± 19.2	42.4 ± 8.1	41.45 ± 11.1	52.7 ± 13.0	26.92 ± 5.3	78 ± 5.3	137.4 ± 15.3	81.0 ± 11.2
POST	100.26 ± 21.5	42.3 ± 7.8	42.3 ± 12.14	53.89 ± 13.4	29.18 ± 5.2	76.2 ± 6.8	131.0 ± 7.3	79.6 ± 9.9
Mean Difference	2.2 ± 2.8	-0.1 ± 1.1	.92 ± 2.21	1.2 ± 1.22	2.26 ± 4.5	-1.8 ± 4.7	-6.4 ± 12.5	-1.4 ± 3.5
RST (p-value)	-4.5 (0.31)	0.5 (1.0)	-1.5 (0.81)	-6.5 (0.13)	-2.5 (0.63)	3.5 (0.50)	3 (0.38)	2.5 (0.50)
Cohens d	0.11	0.01	0.07	0.09	0.43	0.29	0.53	0.13

Metabolic Profile

N=5	FBG (mg/dL)	HbA1c (%)	Total C (mg/dL)	TG (mmol/L)	HDL (mg/dL)	LDL (mg/dL)
PRE	159.7 ± 37	7.14 ± 0.8	186.4 ± 61.4	173 ± 73.6	47.2 ± 12.4	105.4 ± 42.6
POST	144.8 ± 29.5	6.84 ± 0.8	179.6 ± 44.7	147.2 ± 21.6	48.6 ± 14.9	101.4 ± 34.7
Mean Difference	-14.9 ± 33.4	-0.3 ± .28	-6.8 ± 24.7	-25.8 ± 57	1.4 ± 4.2	-4.0 ± 12.6
RST (p-value)	3.5 (0.44)	3 (0.25)	2.5 (0.63)	3.5 (0.44)	-2 (0.63)	2 (0.63)
Cohens d	0.45	0.37	0.13	0.48	0.10	0.10

Oral Glucose Tolerance Test (Glucose [mg/dL])

N=5	FBG	60-min	120-min
PRE	159.7 ± 32.2	324 ± 41.9	304.7 ± 60.8
POST	144.8 ± 25.86	294.5 ± 55.5	273.0 ± 61.6
Mean Difference	-14.9 ± 33.4	-29.5 ± 24.4	-31.7 ± 51.5
RST (p-value)	3.5 (0.44)	7.5 (0.06)	4.5 (0.31)
Cohens d	0.45	0.60	0.52

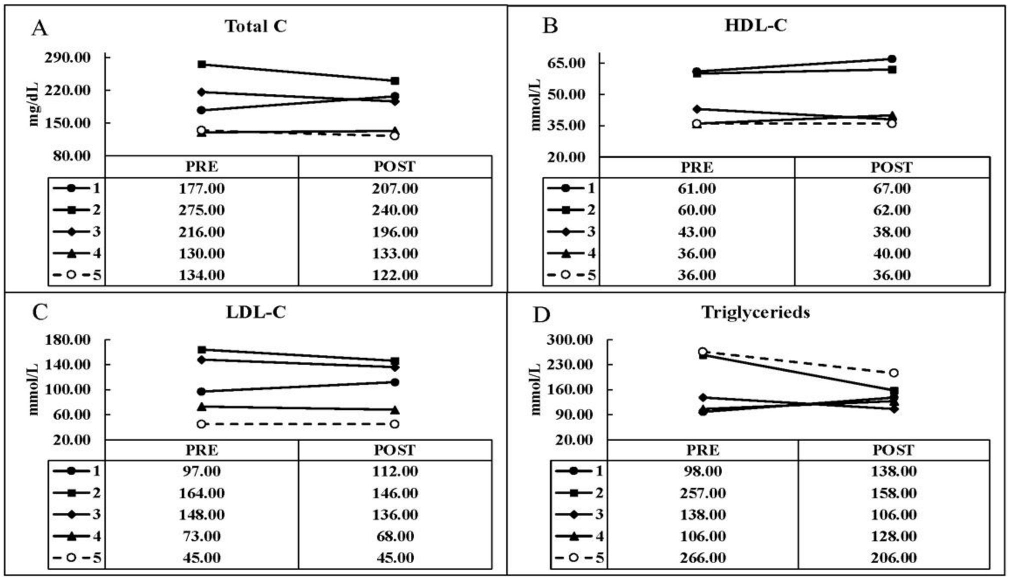


Figure 3. Individual participant data for markers of lipid profile; A)Total Cholesterol, B) High-density Lipoprotein Cholesterol, C) Low-density Lipoprotein Cholesterol, D) Triglycerides. All markers are expressed as absolute values prior to and following the 16-week HIBC intervention.

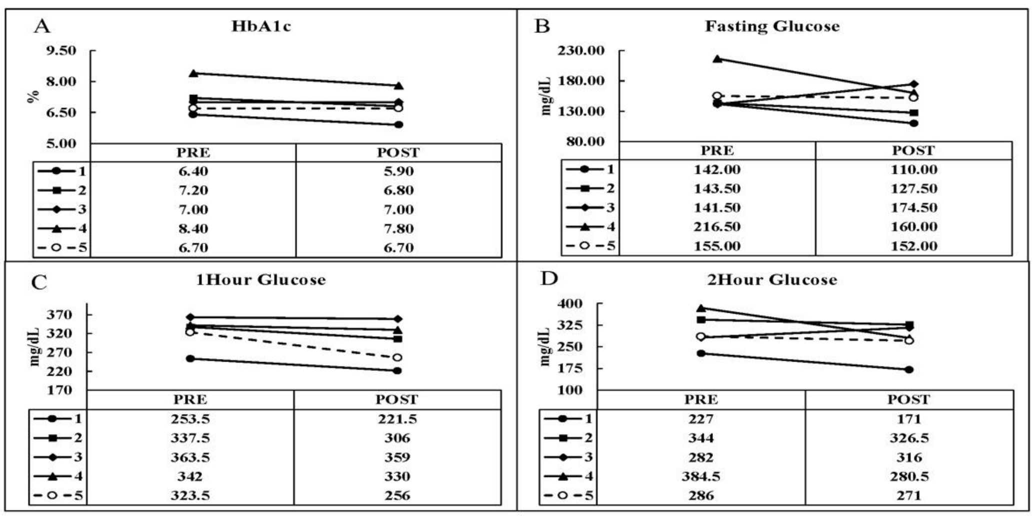


Figure 4. Individual participant data for markers of glucose control (A) and oral glucose tolerance test (B-C); A) Glycosylated Hemoglobin, B) Fasting Blood Glucose, C) Blood Glucose at 1 hour post OGTT, D) Blood Glucose at 2 hour post OGTT. All markers are expressed as absolute values prior to and following the 16-week HIBC intervention.

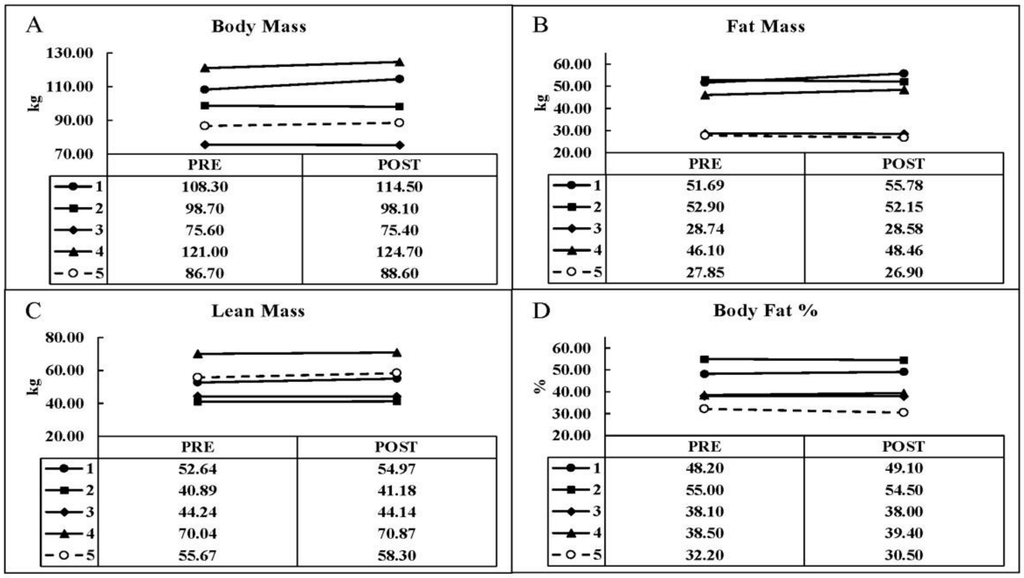


Figure 5. Individual participant data for markers of body composition; A) Total Body Mass, B) Fat Mass, C) Lean Mass, D) Percent Body Fat. All markers are expressed as absolute values prior to and following the 16-week HIBC intervention.

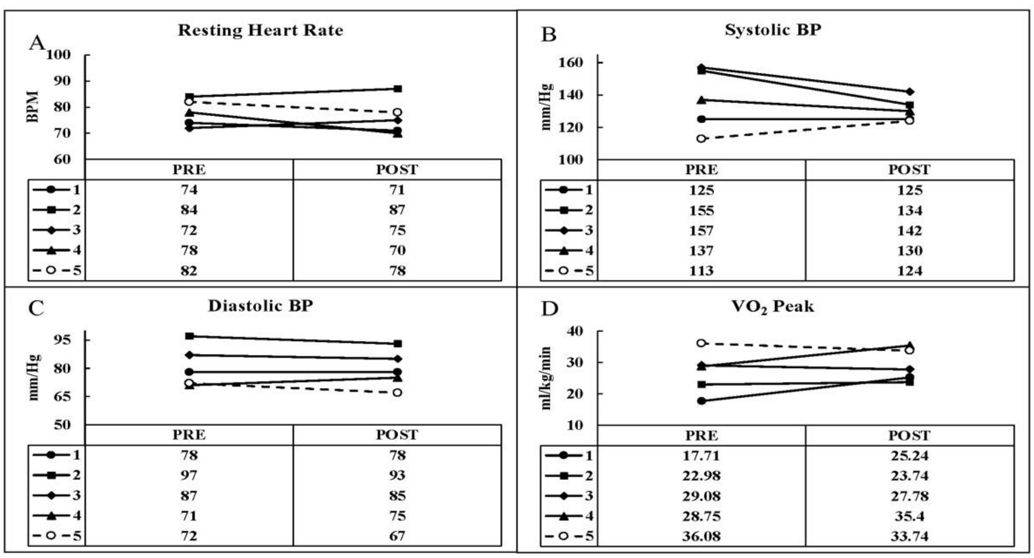


Figure 6. Individual participant data for markers of cardiovascular health (A-C) and cardiovascular fitness (D); A) Resting Heart Rate, B) Systolic Blood Pressure, C) Diastolic Blood Pressure, D) Oxygen consumption (Peak VO_2). All markers are expressed as absolute values prior to and following the 16-week HIBC intervention.

DISCUSSION

The purpose of this pilot was to evaluate the effectiveness of the HIBC interventions on metabolic biomarkers, body composition, and fitness, in adults with T2DM. The primary findings of this study were trends toward improvements in LM, VO_{2max}, SBP, FBG, HbA1c, Total C, TG, and OGTT. Though not significantly different form baseline measures, these outcomes reflect similar absolute observations of commonly prescribed interventions (6, 9, 20).

Exercise is a well-known effective intervention for those diagnosed with T2DM, with several different modalities examined over recent years (3, 9, 10, 12, 16, 22, 28). Perhaps the most widely administered exercise interventions in this population are aerobic-based modalities, which are a cornerstone of the American Diabetes Association recommendations (i.e., 3-5 days of 150-minutes of moderate aerobic exercise a week) (10). For instance, Kadoglou et al. evaluated the effects of a 6-month aerobic exercise training intervention comprised of four supervised sessions lasting 30-45-minutes per week for at 50-75% VO_{2peak} on 30 participants with T2DM (19). The primary results of this intervention were a reduction in HbA1c (%) of 0.63 ± 0.41%, and in FBG of 18.58 ± 4.42 mg/dl, a decrease in systolic blood pressure of 6.9 ± 5.19 mmHg, and an increase in VO_{2Peak} of 3.66 ± 1.68 ml/kg/min. Additionally, Karstoft et al., (20) in 2012 evaluated and compared continuous walking (n=12) vs. walking intervals (n=12) in diagnosed T2DM over a period of 4months. Overall, no changes in VO_{2max} or glucose regulation were observed in the continuous walking group; however, the intermittent walking group improved glycemic control, fasting insulin, and VO_{2max} (20). The findings of the aforementioned studies are similar with those of the current study, which resulted in a 14.9 mg/dL reduction in FBG, 0.3% drop in HbA1c, VO_{2max} improvement of 2.26 ml/kg/min, and a reduction in systolic blood pressure of 6.4 mmHg. In spite of an under-powered sample, these reductions demonstrate HIBC may provide improvements similar to those of traditionally prescribed aerobic based exercise interventions with a fraction of the time commitment.

Another commonly prescribed modality for this population is resistance training (6, 9, 10). Castaneda et. al,(6) evaluated 16-weeks of a progressive resistance training program using 5 pneumatic exercise machines designed to engage the full body. For this intervention HbA1c decreased from 8.7 ± 0.3% to 7.6 ± 0.2%, and lean mass increased from 44.3 ± 1.7kg to 45.5 ± 1.9 kg, while resting blood glucose did not change. Importantly, when prescribing aerobic or resistance based exercise independently, results tend to be mixed, and outcomes are often better with combined resistance and aerobic exercise training. This point is supported by several review papers (10, 32, 33, 41). This dynamic was exemplified by Church et. al., who evaluated resistance training, aerobic training, and combined training over a 9 month period. The aerobic training only group yielded no significant changes in HbA1c (-0.24%), the resistance training prescription group also produced no significant changes in HbA1c (-0.16%), while the combination aerobic and resistance training group was the only intervention in which meaningful changes in HbA1c (-0.34%) and maximal oxygen uptake (1.0 mL/kg/min) were observed (9). These findings are mixed when compared to the finding of the current pilot. Though HbA1c did not change as significantly as experienced in Castaneda et. al,(6) which was approximately 1% reduction, our findings were equal to, if not greater than those experienced by Church et. al (9). This may be explained by differences in resistance prescribed in Castaneda, et. al,(6), whereas the resistance in the HIBC intervention was relative bodyweight. A notable observation from the HIBC study was the 1.19 ± 1.2 kg increase in LM, which was similar to that of the findings of Castaneda et. al, (6) despite the differences in the training load. Furthermore, these improvements were realized in a training program requiring an initial 15-minutes and a maximum of 40-minutes per week, while the program employed by Casteneda et al. (6) required approximately 135-minutes of training each week. Importantly, the changes in body composition should be taken within the context of a non-controlled diet, future studies should account for dietary influences on composition.

A rapidly growing area of interest in exercise interventions targeting patients with T2DM is HIT (16-18, 25, 30, 31, 35, 37). The

HIT intervention typically requires a lower volume, dose, and/or time requirement or some combination of these in order to achieve positive physiological outcomes. In a feasibility study performed by Terada et al., (37) a HIT protocol starting with seven 1-minute intervals at 100% VO_2 Reserve (VO_2R) with 3-minutes recovery at 20% VO_2R was compared to continuous moderate exercise (40% VO_2R for 30-minutes) in individuals with T2DM over a 12 week period. Investigators found that HIT equaled continuous exercise in reducing subcutaneous fat, but produced no changes in HbA1c; however, this may have been due to the intervention's duration (i.e. 12-weeks). HIT has also been shown to improve glucose regulation in short periods of time (i.e. 2-weeks). Little et. al.,(25) demonstrated the effectiveness of a two week HIT intervention consisting of six supervised sessions in eight participants with T2DM. Each exercise session consisted of 10 x 60 seconds cycling intervals and 60 seconds of rest, with a total exercise time requirement of 30-minutes per week, which is an 80% lower time requirement than the current guidelines recommend (10). The results demonstrated no changes in body mass, while 24-hour continuous glucose monitoring showed average plasma glucose decreased from 7.6 ± 1.0 to 6.6 ± 0.7 mmol/l (25). Though metabolic profile improvements appear to be similar to that of the HIBC pilot, these studies do not demonstrate comparable changes in LM. Additionally, the lack of full body recruitment appears to be a limitation of the HIT style intervention and may ultimately reduce the overall program effectiveness.

It is clear that these commonly prescribed interventions are capable of eliciting positive physiological outcomes in participants with T2DM (3, 10, 22); however, they have done little to slow the progression of the disease in the population (1, 4, 8). A prominent issue related to the continuing growth in prevalence of T2DM is the lack of participation in or adherence to exercise and physical activity (23). To this end, several studies have evaluated barriers related to starting or maintaining exercise programs (23, 24, 26, 29, 34, 36, 42). A commonly reported barrier to exercise is lack of time (23, 24). Whether it be related to time at work, home responsibilities, or distance to fitness facility, participants are finding it difficult to engage in regular exercise. This barrier is especially problematic as it relates to traditional aerobic, resistance, or combined training which carry a time commitment of 150-minutes or more per week (10). HIT interventions target this barrier by reducing the time commitment to between 15-minutes (5-x-1 HIT) and approximately 40-minutes per week (7-bx-1 HIT)(30); however, HIT appears to provide barriers or limitations of its own, as they have been shown to be difficult to maintain long term, due, in part, to intensity related discomfort (29, 30). An additional limitation to HIT training is the use of a single modality (i.e., cycle ergometer)(16, 17, 30), and therefore it lacks benefits associated with resistance training and whole-body muscle recruitment/adaptation. The HIBC intervention appears to address these common issues and therefore may serve as an attractive alternative to commonly prescribed interventions in those with T2DM.

With a litany of effective exercise interventions available, participant adherence is perhaps one of the most important variables to consider. Interventions that show potent improvements in metabolic function lose their value if and when patients do not adhere to the protocols. Self-reported adherence for the current intervention was 92.6 ± 8.8% over the 16-week period demonstrating a similar adherence rate to widely accepted interventions. For instance, aerobic interventions from Kadoglou et al. and Kartsoft et al., demonstrated adherence rates of 92 ± 4% over 6-months and 89 ± 4% over 16-

weeks, respectively; while, Castaneda et al., reported a 90 ± 10% over a 16-week resistance training intervention. The demonstration of intervention adherence is only one step towards understanding the long-term effectiveness of a given intervention. The current findings suggest that the HIBC will maintain a high level of adherence within the confines of the study; however, future projects should provide follow up surveys to assess long-term adherence.

CONCLUSIONS

This pilot investigation suggests that the HIBC intervention may present an alternative option for those with T2DM, in that it demonstrated changes in metabolic profiles similar in magnitude to both aerobic and HIT interventions (19), while also suggesting increases in lean mass similar to those observed following resistance training interventions (6). Though the main findings of this study were not statistically significant, the observed changes provide the rationale for further investigation of the HIBC protocol and its feasibility. This pilot also highlighted the need for future studies to account for diet and caloric intake, long-term assessments in adherence, and a more robust sample population.

FUNDING SOURCES

There were no funding sources for this study

REFERENCES

1. American Diabetes A. Economic costs of diabetes in the u.S. In 2017. Diabetes Care 41(5):917-928, 2018.
2. Bartoli E, Fra GP, Carnevale Schianca GP. The oral glucose tolerance test (ogtt) revisited. Eur J Intern Med 22(1):8-12, 2011.
3. Boule NG, Haddad E, Kenny GP, Wells GA, Sigal RJ. Effects of exercise on glycemic control and body mass in type 2 diabetes mellitus: A meta-analysis of controlled clinical trials. JAMA 286(10):1218-1227, 2001.
4. Bullard KM, Cowie CC, Lessem SE, Saydah SH, Menke A, Geiss LS, Orchard TJ, Rolka DB, Imperatore G. Prevalence of diagnosed diabetes in adults by diabetes type - united states, 2016. MMWR Morb Mortal Wkly Rep 67(12):359-361, 2018.
5. Buresh R, Hornbuckle LM, Garrett D, Garber H, Woodward A. Associations between measures of health-related physical fitness and cardiometabolic risk factors in college students. J Am Coll Health 66(8):754-766, 2018.
6. Castaneda C, Layne JE, Munoz-Orians L, Gordon PL, Walsmith J, Foldvari M, Roubenoff R, Tucker KL, Nelson ME. A randomized controlled trial of resistance exercise training to improve glycemic control in older adults with type 2 diabetes. Diabetes Care 25(12):2335-2341, 2002.
7. Chin APMJ, van Uffelen JG, Riphagen I, van Mechelen W. The functional effects of physical exercise training in frail older people : A systematic review. Sports Med 38(9):781-793, 2008.
8. Cho NH, Shaw JE, Karuranga S, Huang Y, da Rocha Fernandes JD, Ohlrogge AW, Malanda B. Idf diabetes atlas: Global estimates of diabetes prevalence for 2017 and projections for 2045. Diabetes Res Clin Pract 138:271-281, 2018.

9. Church TS, Blair SN, Cocreham S, Johannsen N, Johnson W, Kramer K, Mikus CR, Myers V, Nauta M, Rodarte RQ, Sparks L, Thompson A, Earnest CP. Effects of aerobic and resistance training on hemoglobin a1c levels in patients with type 2 diabetes: A randomized controlled trial. JAMA 304(20):2253-2262, 2010.

10. Colberg SR, Sigal RJ, Yardley JE, Riddell MC, Dunstan DW, Dempsey PC, Horton ES, Castorino K, Tate DF. Physical activity/exercise and diabetes: A position statement of the american diabetes association. Diabetes Care 39(11):2065-2079, 2016.

11. Fahlman MM, Topp R, McNevin N, Morgan AL, Boardley DJ. Structured exercise in older adults with limited functional ability. J Gerontol Nurs 33(6):32-39, 2007.

12. Fealy CE, Nieuwoudt S, Foucher JA, Scelsi AR, Malin SK, Pagadala M, Cruz LA, Li M, Rocco M, Burguera B, Kirwan JP. Functional high-intensity exercise training ameliorates insulin resistance and cardiometabolic risk factors in type 2 diabetes. Exp Physiol 103(7):985-994, 2018.

13. Feito Y, Heinrich KM, Butcher SJ, Poston WSC. High-intensity functional training (hift): Definition and research implications for improved fitness. Sports (Basel) 6(3)2018.

14. Foster C, Jackson AS, Pollock ML, Taylor MM, Hare J, Sennett SM, Rod JL, Sarwar M, Schmidt DH. Generalized equations for predicting functional capacity from treadmill performance. Am Heart J 107(6):1229-1234, 1984.

15. Garber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee IM, Nieman DC, Swain DP, American College of Sports M. American college of sports medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: Guidance for prescribing exercise. Med Sci Sports Exerc 43(7):1334-1359, 2011.

16. Gibala MJ, Little JP, Macdonald MJ, Hawley JA. Physiological adaptations to low-volume, high-intensity interval training in health and disease. J Physiol 590(5):1077-1084, 2012.

17. Gillen JB, Little JP, Punthakee Z, Tarnopolsky MA, Riddell MC, Gibala MJ. Acute high-intensity interval exercise reduces the postprandial glucose response and prevalence of hyperglycaemia in patients with type 2 diabetes. Diabetes Obes Metab 14(6):575-577, 2012.

18. Jelleyman C, Yates T, O'Donovan G, Gray LJ, King JA, Khunti K, Davies MJ. The effects of high-intensity interval training on glucose regulation and insulin resistance: A meta-analysis. Obes Rev 16(11):942-961, 2015.

19. Kadoglou NP, Iliadis F, Angelopoulou N, Perrea D, Ampatzidis G, Liapis CD, Alevizos M. The anti-inflammatory effects of exercise training in patients with type 2 diabetes mellitus. Eur J Cardiovasc Prev Rehabil 14(6):837-843, 2007.

20. Karstoft K, Winding K, Knudsen SH, Nielsen JS, Thomsen C, Pedersen BK, Solomon TP. The effects of free-living

interval-walking training on glycemic control, body composition, and physical fitness in type 2 diabetic patients: A randomized, controlled trial. Diabetes Care 36(2):228-236, 2013.

21. Kerner W, Bruckel J, German Diabetes A. Definition, classification and diagnosis of diabetes mellitus. Exp Clin Endocrinol Diabetes 122(7):384-386, 2014.
22. Kirwan JP, Sacks J, Nieuwoudt S. The essential role of exercise in the management of type 2 diabetes. Cleve Clin J Med 84(7 Suppl 1):S15-S21, 2017.
23. Korkiakangas EE, Alahuhta MA, Laitinen JH. Barriers to regular exercise among adults at high risk or diagnosed with type 2 diabetes: A systematic review. Health Promot Int 24(4):416-427, 2009.
24. Lidegaard LP, Schwennesen N, Willaing I, Faerch K. Barriers to and motivators for physical activity among people with type 2 diabetes: Patients' perspectives. Diabet Med 33(12):1677-1685, 2016.
25. Little JP, Gillen JB, Percival ME, Safdar A, Tarnopolsky MA, Punthakee Z, Jung ME, Gibala MJ. Low-volume high-intensity interval training reduces hyperglycemia and increases muscle mitochondrial capacity in patients with type 2 diabetes. J Appl Physiol (1985) 111(6):1554-1560, 2011.
26. Mogre V, Johnson NA, Tzelepis F, Shaw JE, Paul C. A systematic review of adherence to diabetes self-care behaviours: Evidence from low-and middle-income countries. J Adv Nurs 2019.
27. Navalta JW, Stone WJ, Lyons TS. Ethical issues relating to scientific discovery in exercise science. Int J Exerc Sci 12(1):1-8, 2019.
28. Nieuwoudt S, Fealy CE, Foucher JA, Scelsi AR, Malin SK, Pagadala M, Rocco M, Burguera B, Kirwan JP. Functional high-intensity training improves pancreatic beta-cell function in adults with type 2 diabetes. Am J Physiol Endocrinol Metab 313(3):E314-E320, 2017.
29. Perri MG, Anton SD, Durning PE, Ketterson TU, Sydeman SJ, Berlant NE, Kanasky WF, Jr., Newton RL, Jr., Limacher MC, Martin AD. Adherence to exercise prescriptions: Effects of prescribing moderate versus higher levels of intensity and frequency. Health Psychol 21(5):452-458, 2002.
30. Phillips BE, Kelly BM, Lilja M, Ponce-Gonzalez JG, Brogan RJ, Morris DL, Gustafsson T, Kraus WE, Atherton PJ, Vollaard NBJ, Rooyackers O, Timmons JA. A practical and time-efficient high-intensity interval training program modifies cardio-metabolic risk factors in adults with risk factors for type ii diabetes. Front Endocrinol (Lausanne) 8:229, 2017.
31. Shaban N, Kenno KA, Milne KJ. The effects of a 2 week modified high intensity interval training program on the homeostatic model of insulin resistance (homa-ir) in adults with type 2 diabetes. J Sports Med Phys Fitness 54(2):203-209, 2014.
32. Sigal RJ, Kenny GP, Boule NG, Wells GA, Prud'homme D, Fortier M, Reid RD,

Tulloch H, Coyle D, Phillips P, Jennings A, Jaffey J. Effects of aerobic training, resistance training, or both on glycemic control in type 2 diabetes: A randomized trial. Ann Intern Med 147(6):357-369, 2007.

33. Snowling NJ, Hopkins WG. Effects of different modes of exercise training on glucose control and risk factors for complications in type 2 diabetic patients: A meta-analysis. Diabetes Care 29(11):2518-2527, 2006.

34. Spiteri K, Broom D, Bekhet AH, de Caro JX, Laventure B, Grafton K. Barriers and motivators of physical activity participation in middle-aged and older-adults - a systematic review. J Aging Phys Act:1-80, 2019.

35. Stoa EM, Meling S, Nyhus LK, Glenn S, Mangerud KM, Helgerud J, Bratland-Sanda S, Storen O. High-intensity aerobic interval training improves aerobic fitness and hba1c among persons diagnosed with type 2 diabetes. Eur J Appl Physiol 117(3):455-467, 2017.

36. Stutts WC. Physical activity determinants in adults. Perceived benefits, barriers, and self efficacy. AAOHN J 50(11):499-507, 2002.

37. Terada T, Friesen A, Chahal BS, Bell GJ, McCargar LJ, Boule NG. Feasibility and preliminary efficacy of high intensity interval training in type 2 diabetes. Diabetes Res Clin Pract 99(2):120-129, 2013.

38. Thompson WR. Worldwide survey of fitness trends for 2016 10th anniversary edition. Acsms Health Fit J 19(6):9-18, 2015.

39. Thompson WR. Worldwide survey of fitness trends for 2017. Acsms Health Fit J 20(6):8-17, 2016.

40. Thompson WR. Worldwide survey of fitness trends for 2018 the crep edition. Acsms Health Fit J 21(6):10-19, 2017.

41. Umpierre D, Ribeiro PA, Kramer CK, Leitao CB, Zucatti AT, Azevedo MJ, Gross JL, Ribeiro JP, Schaan BD. Physical activity advice only or structured exercise training and association with hba1c levels in type 2 diabetes: A systematic review and meta-analysis. JAMA 305(17):1790-1799, 2011.

42. Venkataramani M, Pollack CE, Yeh HC, Maruthur NM. Prevalence and correlates of diabetes prevention program referral and participation. Am J Prev Med 56(3):452-457, 2019.

43. WILCOXON F. Individual comparisons of grouped data by ranking methods. J Econ Entomol 39:269, 1946.