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Original Research Article

Proof of concept: can REHIT offset unfavorable cardiometabolic profiles in a sedentary disabled population?

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ABSTRACT

Introduction: Reduced exertion high intensity training (REHIT), is a variation of high intensity interval training (HIIT) utilizing a minimal amount of exercise and exertion to elicit metabolic health benefits, including reduced blood pressure, improved lipid profile, improved glucose sensitivity, reduced waist circumference, and reduced BMI. The aim of this proof of concept study was twofold; (1) to investigate the effects of interrupting prolonged sedentary bouts with a daily REHIT upper-body session on cardiometabolic risk factors in individuals with mobility disabilities and, (2) to determine the feasibility of implementing a REHIT program in this population. **Methods:** Two females (56±2.2 years) participated in this repeated measures experimental design study. The study occurred over two weeks. Week one was the control, subjects maintained their normal activity levels. During week two, subjects participated in a once-a-day, eight-minute, at-home, upper-body REHIT session with a light-medium resistance band. Cardiometabolic profiles were measured on days 1, 8, and 15. This study was not intended to identify significant, generalizable, health benefits due to the sample size, and instead explored the feasibility of the intervention as it may apply to a larger sample. Because this was a proof-of-concept study, with a small n, the data was analyzed descriptively. **Results:** Two trends in cardiovascular health biomarkers were found post-REHIT intervention: LDL decreased 15.5±0.5 mg/dL and TC decreased 16.5±2.5 mg/dL. There were no consistent trends in any of the other outcomes, including OGTT and MetS z-score. However, trends were noted in relation to total activity level. The greatest cardiometabolic profile benefits were observed during the most active week of the study. Distinct individual differences were noted. Two of the three feasibility criteria were met: Notably, progression criterion 1: Recruitment and retention rates were deemed unlikely to be feasible, most likely due to COVID-19. Progression criterion 2: The acceptability of the intervention did meet the criterion threshold and may be suitable in the current form for any related future studies. Progression criterion 3: Outcomes showed two positive trends in metabolic health but did not show any other trends. **Conclusion:** Two of the three criteria for progression to a full-scale study were met. Therefore, using REHIT in sedentary and disabled populations may be an effective intervention to increase energy expenditure and improve cardiometabolic health in these populations.

KEY WORDS: Arm Ergometry, Cardiometabolic Profile, Disability Exercise, Mobility.

INTRODUCTION

The cardiovascular consequences of prolonged sitting in populations who are completely sedentary and/or those who are physically inactive have become a focus in both the field of exercise physiology and public health. Sedentary behavior is defined as participation in activities such as sitting and reclining during waking hours that do not increase energy expenditure substantially[1]. Physical inactivity is defined as not participating in planned and structured exercise regularly[2]. While sedentary behavior and physical inactivity are distinct concepts they have both been associated with increased risk of developing cardiovascular diseases (CVD), metabolic syndrome, obesity, cancer, and type 2 diabetes[1,2,3]. Epidemiological research has determined that the dose-response relationship between activity and disease is steep, with notable decreases in activity associated with increases in morbidity[4]. What is less appreciated is that time spent in self-reported sedentary behavior has also been recognized as a unique risk factor sharing a detrimental association with morbidity[5]. These risk factors are independent of each other, meaning that even those who are physically active, at or above American College of Sports Medicine (ACSM) recommendations, and spend prolonged periods in sedentary behavior, are still at increased risk for morbidity[6].

Displacing sedentary time with either light intensity activities or moderate to vigorous physical activity (MVPA) allows for greater energy expenditure, more muscular contractions, and the health benefits associated with increased movement[7]. Research has begun to focus on the detrimental health risks of physical inactivity which has led to the development and promotion of a whole-day approach[8]. This whole-day approach encourages individuals to include activity in their overall day, increasing both moderate-intensity exercise and light-intensity activity with a focus on the 'non-exercise' part of the activity continuum[9]. Focusing on this part of the activity continuum, promotes breaks in sedentary time, increased light-intensity activity, such as activities of daily living, and promotes a decrease in physical inactivity. Interrupting prolonged sedentary behavior by standing[10], walking [11], or using an arm bike[12] for 1-5 minutes every hour has been shown to be beneficial in reducing cardiometabolic disease risk. Evidence has shown a favorable association between breaks in sedentary time and cardiometabolic health, with a greater number of breaks associated with a greater decrease in cardiometabolic risk factors[10,11,12]. Focus on reducing sedentary time, and the way it is accumulated may play at least as important, if not more important, role as promoting physical activity in maintaining healthy weight and preventing chronic disease[13].

Interrupting prolonged sedentary bouts as an intervention to promote health tackles the challenge of inactivity and may be particularly relevant for adults with mobility disabilities, such as those who use a wheelchair, stroke survivors who cannot walk far distances, individuals with chronic pain syndrome (CPS) that limit their ability to walk, or those suffering from multiple sclerosis (MS) or spinal cord injuries (SCI). Sedentary populations experience a higher incidence and prevalence of chronic health complications and exhibit higher rates of mortality than the general population[14]. Investigating the interruption of prolonged sedentary bouts with upright activities, that still allow one to remain seated, may have important clinical relevance for individuals with restricted mobility.

Previous strategies to break up sedentary behavior include, engaging in movement such as walking every 30 minutes for approximately 5 minutes[10,15]. However, this approach does not apply to a mobility-disabled population. A more plausible approach in this population may be breaking up sedentary time with seated upper-body activity which has been shown to regulate metabolic health in obese sedentary individuals[12]. Indeed, McCarthy et al. (2017) showed that five minutes of seated arm ergometry every 30 minutes significantly reduced mean blood glucose and mean insulin response[12]. These findings cannot be attributed to a change in posture because breaks were implemented while maintaining a seated position, and therefore, can be attributed to muscle activation.

Another exercise intervention used to enhance movement and benefit health in sedentary populations is reduced exertion high intensity training (REHIT). For instance, in a six-week protocol, with REHIT done 10 minutes per day, three days a week, aerobic capacity and insulin sensitivity significantly increased, despite a low rating of perceived exertion (RPE)[15]. Similarly, significant improvements in HBA1c, glucose measures, systolic blood pressure, and waist circumference were noted after three weeks of a similar protocol[16]. REHIT has also been shown to be more effective at improving cardiorespiratory fitness and cardiometabolic health than traditional moderate-intensity continuous training in sedentary individuals[17].

The aim of this study was twofold; (1) to investigate the effect of interrupting prolonged sedentary bouts with a daily REHIT, upper-body, aerobic session on cardiometabolic health measured by lipid profiles, glucose tolerance, blood pressure, waist circumference, and body mass index in individuals who were sedentary due to a mobility disability, and (2) to determine the feasibility of implementing a REHIT program in this population. It was hypothesized that there would be a notable improvement in cardiometabolic biomarkers after a one-week intervention of upper-body aerobic REHIT activity.

METHODS

Subjects

Subjects were screened and identified through a database from a local health and wellness program as well as by referral through local physicians and physical therapists. Four female sedentary walker or wheelchair users were screened for this study. Of those screened, three subjects volunteered for this study and later, one dropped out during the control week due to an illness unrelated to the study. To participate in this study, subjects had to have a mobility impairment limiting their ability to walk for long periods, identify as being sedentary for eight or more hours a day (measured by PACE patient-centered assessment and counseling for exercise questionnaire), have at least two cardiometabolic risk factors using ACSM risk stratification (Figure 1), and had to be able to exercise using a light-medium resistance band for upper-body aerobic training. Exclusion criteria included: pregnancy, under the age of 18, or using lipid-lowering or anti-hypertensive medications.

Risk Stratification Scoring

Positive Risk Factors	Defining Criteria	Points
Age	Men ≥ 45 years, Women ≥ 55 years	+1
Family History	Myocardial infarction, coronary revascularization, or sudden death before 55 years of age in father of other 1st degree male relative or before 65 years of age in mother or other 1st degree female relative	+1
Cigarette Smoking	Current cigarette smoker or those who quit within the previous six months, or exposure to environmental tobacco smoke (i.e., secondhand smoke)	+1
Sedentary Lifestyle	Not participating in at least 30 minutes of moderate-intensity physical activity on at least three days/week for at least three months	+1
Obesity	Body mass index ≥30 kg/m^2 or waist girth >102 cm (40 inches) for men >88 cm (35 inches) for men	+1
Dyslipidemia	Low-density lipoprotein (LDL) cholesterol ≥ 130mg/dL (3.37 mmol/L) or high-density lipoprotein (HDL) cholesterol <40mg/dL (1.04mmol/L) or currently on lipid-lowering medication; If total serum cholesterol is all that is available, use serum cholesterol >200 mg/dL (5.18mmol/L)	+1
Prediabetes	Fasting plasma glucose ≥100 mg/dL (5.50 mmmol/L) but <126 mg/dL (6.93 mmol/L) or impaired glucoe tolerance (IGT) where a two-hour oral glucose tolerance test (OGTT) value is ≥140 mg/dL (7.70 mmol/L), but <200 mg/dL (11.00mmol/L)	+1
Negative Risk Factors	**Defining Criteria**	**Points**
High HDL Cholesterol	≥60 mg/dL (1.55 mmol/L)	-1

Figure 1. ACSM Risk Stratification Scoring.

The subjects filled out an informed consent before participating in the study. They were informed participation was optional and they could drop out at any time without penalty. Intake and testing took place at the University Human Performance Laboratory (elevation: 2348 meters). There was no specific location protocol for the exercise sessions because they were meant to be done at the convenience of the subject in their own home or work setting. This study was reviewed and approved by the University's Institutional Review Board.

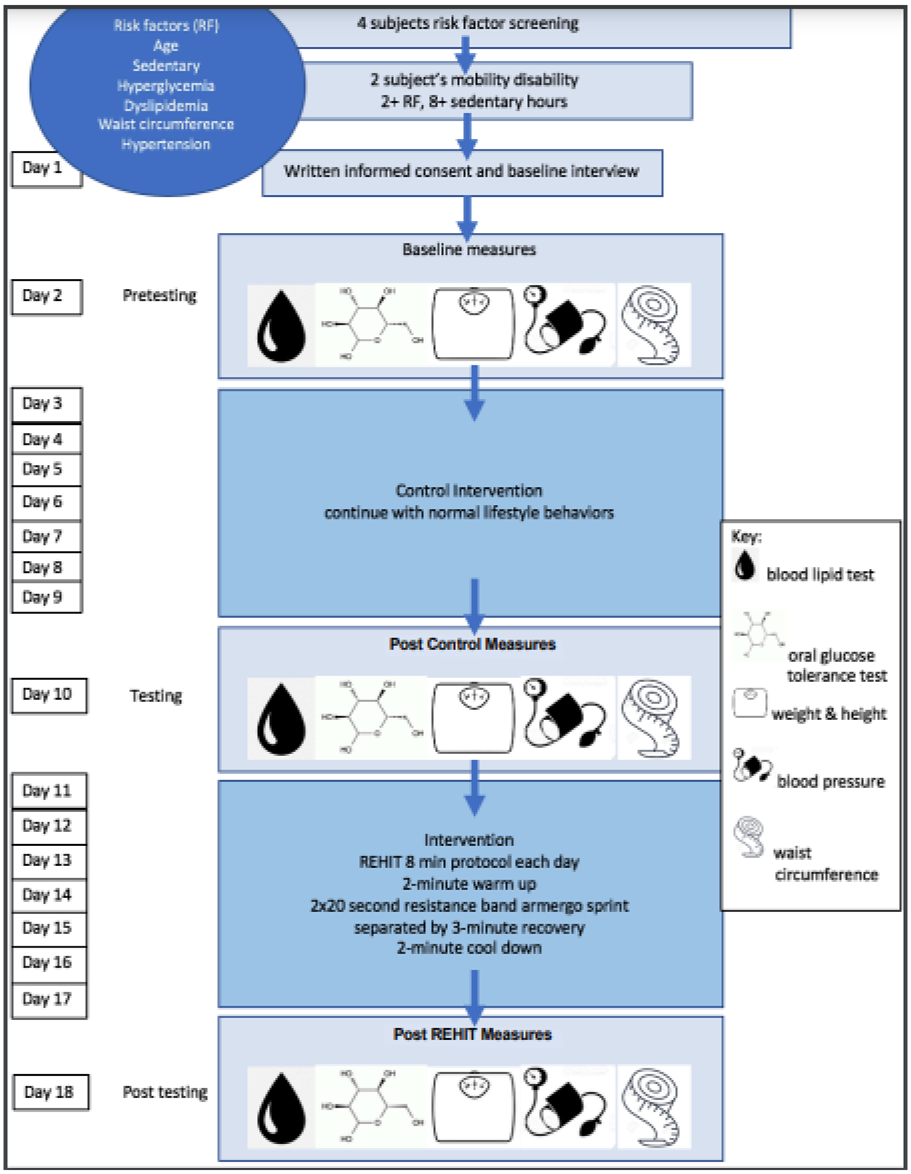

Figure 2. Experimental flow chart.

Experimental Design

In this two-week, repeated-measures, proof of concept study, subjects participated in the control intervention for the first week and then participated in the REHIT intervention the second week. No washout was utilized. No crossover was utilized because no benefit was seen in terms of familiarization. During the REHIT intervention, subjects arm cycled using a resistance band once per day for eight minutes. Subjects were asked to complete this intervention in the middle of their day to break up sedentary behavior.

Before participating in the study, potential subjects were screened to determine if they met the inclusion criteria by a health history questionnaire, sedentary behavior (PACE) questionnaire, resting blood pressure (RBP), waist circumference (WC), and fasted blood lipids and glucose measurements. Subjects that met the criteria underwent their first testing session which consisted of the International Physical Activity Questionnaire (IPAQ), RBP, heart rate (HR), WC, body weight (BW), height (Ht), fasted blood lipids, and fasted oral glucose tolerance (OGTT). For the testing appointments subjects were asked to meet the principal investigator (PI) at the laboratory where they completed questionnaires and took measurements listed above. The testing was repeated two more times: Once after week one and once after week two of the study. Subjects were asked to record and replicate their diets for 24 hours before each testing session. Refer to the experimental flow chart (Figure 2).

Procedures

Testing

Subjects underwent testing on days 1, 8, and 15. Testing was done on the same day of the week, at the same time of day. Testing consisted of Ht, WT, WC, RBP, fasted blood lipids, OGTT, and answering the IPAQ.

Height and weight

A scale (Tanita, Arlington Heights, IL) with a built-in measurement tool was used to measure the height (cm) and weight (kg) of the subject. The subject was asked to remove shoes and height was measured at the top of the head, with hair pressed down. Subjects were also weighed without shoes or bulky clothing. Their height and weight were later used to calculate body mass index (BMI, kg/m^2).

Waist circumference

A measuring tape (DJO Global, Vista, CA) was wrapped around the subject's torso at the narrowest point between the umbilicus and the end of the sternum. The subject was instructed to inhale deeply, then exhale completely and hold the exhale as the measurement was being taken to ensure the subject was not holding in his/her stomach. Three measurements of waist circumference (cm) were taken and averaged.

Resting blood pressure

After being seated for five minutes, a blood pressure cuff (Mabis Healthcare in., Lake Forest, IL) was placed approximately one inch above the antecubital fossa of the subject's left arm and inflated to 220 mmHg.

The pressure was released and the PI listened for the first and last Korotkoff sounds with a stethoscope (Mabis Healthcare Inc., Lake Forest, IL). This process was repeated three times, on the left arm, with a one-minute rest in between each reading, BP readings were then averaged.

Fasting blood lipid and glucose testing

Before testing, subjects were asked to fast for at least 12 hours. Subjects were asked to wash their hands with soap and warm water then their preferred finger was cleaned with an alcohol swab and allowed to air dry. The tip of their finger was punctured using a lancet (Medipurpose, Brussels, Belgium), and a finger stick sample was collected into heparin coated 40 μl capillary tube (Abbott, Abbott Park, IL). Samples were dispensed immediately onto a commercially available test cassette (Abbott, Abbott Park, IL) for analysis in an LDX Cholestech analyzer (Abbott, Abbott Park, IL). The LDX Cholestech measured total cholesterol (TC), high density lipoprotein (HDL) cholesterol, low density lipoprotein (LDL) cholesterol, triglycerides, and blood glucose. A daily optics check was performed on the LDX Cholestech analyzer used for the study. Subjects were not allowed to eat any food until results were determined.

Oral glucose tolerance test

Insulin sensitivity was assessed using an OGTT. Subjects were asked to fast for 12 hours and to refrain from vigorous physical activity and alcohol for 24 hours before the test. Subjects completed a 24-hour food diary before each OGTT. On the day of testing, subjects reported to the laboratory between 7:00 a.m. and 9:30 a.m. Subjects sat resting in a chair while the PI obtained a blood sample via a finger prick with a lancet (Medipurpose, Brussels, Belgium). A glucometer (Contour Next One, Parsippany, NJ) and blood glucose test strip (Contour Next One, Parsippany, NJ) were used to analyze baseline blood glucose. The subject then consumed a commercially available glucose drink (75 g of glucose per 296 ml drink; Azer Scientific, Inc., Morgantown, PA). The subject had approximately five minutes to consume all of the glucose drink. Blood samples were taken immediately after ingestion, every five minutes for the first 30 minutes, and every 15 minutes until a total of two hours was reached. Area under the curve (AUC) for plasma glucose was calculated using the trapezoid model.

IPAQ

Once subjects had completed cholesterol blood work and were in between glucose measure times during OGTT, they were asked to stay seated and fill out the IPAQ.

Metabolic syndrome z-score

In previous research, a continuous risk score assessment scale (MetS z-score) has been used to identify changes in metabolic syndrome (MetS) risk factors following interventions such as moderate intensity continuous training (MICT), high intensity interval training (HIIT), and REHIT[15,16,17].

The MetS severity is a sex-specific calculation using the following equation:

MetS z-score $_{Female}$ = [(50-HDL)/14x5] + [(TG – 150/69)]+ [(BG – 100)/17 x 8] + [WC - 88)/12x5] + [(MAP – 100)/10x1], where HDL = high density lipoprotein; TG = triglycerides; BG= fasted blood glucose; WC= waist circumference; and MAP= mean arterial pressure.

Daily intervention

All subjects completed the control condition the first week (days 1-7), and the intervention the second week (days 8-14). During both weeks subjects were asked to maintain their normal activity and diet patterns. During the intervention, subjects partook in seven, once a day, REHIT sessions. During these sessions, subjects were seated and used a light-medium resistance band (TheraBand, Akron, OH) and rotated arms in a forward circular pattern, similar to an arm ergometer, at their home or workplace. All REHIT sessions lasted seven minutes and 40 seconds and consisted of a two-minute warm-up (RPE 3), a 20-second all-out arm-pedal sprint (RPE 8-10), three-minute active recovery (RPE 3), a 20-second all-out arm-pedal sprint (RPE 8-10), and a two-minute cool-down (RPE 3). Subjects were instructed to set their own timer. A video to follow along with was provided. Subjects were advised to do the REHIT session at approximately mid-day. The PI checked in every day by phone or email, to ensure the subjects were completing the REHIT intervention properly.

Statistical Analyses

No probability statistical analyses were used because this feasibility study did not aim to make inferences from the data. Descriptive statistics were used to summarize the screening and anthropometric data. Basic descriptive statistics including mean and variability of scores were recorded to better understand the outcomes. Area under the curve analyses were performed using GraphPad Prism 8.4 (San Diego, CA, USA). To determine individual MetS z-score delta values (∆) were calculated (post-intervention minus baseline value) to establish the change (∆) in MetS z-score.

RESULTS

Two of the three subjects who consented to partake in the study started the REHIT intervention (67% adherence). Of the two subjects who started the REHIT intervention, both completed all sessions. Subjects (n=2, 100% female) had a mean age of 56 ± 2.2 years, mean BMI of 29.46 ± 10, and mean self-reported sitting time of 11 ± 1 hours due to a disability (Table 1). Overall, LDL and TC decreased from baseline. There were no other trends found following the REHIT intervention (Tables 2 and 3).

Progression criteria

Progression criteria were used to consider whether it would be appropriate to progress to a full-scale study. Based on other similar feasibility studies, these included (1) feasibility to recruit and retain subjects, (2) intervention adherence, and (3) outcomes to assess clinical effectiveness[18].

Screening, recruitment, and retention

A total of four subjects were screened and identified through a database from a local health and wellness program as well as by referral through local physicians and physical therapists. Cardiometabolic health was accessed using ACSM guidelines (Figure 1). All four subjects were eligible to partake in the trial. However, due to precautions of the coronavirus disease 2019 (COVID-19) outbreak, one subject declined to be a part of this study and one subject dropped out due to an illness unrelated to this study. The remaining two subjects showed no signs or symptoms of COVID-19 and completed the study before mandatory stay-at-home precautions were put into place.

Adverse events

No adverse events were reported during, or because of the REHIT intervention.

Outcomes

Table 2 summarizes outcomes to assess clinical effectiveness, which would be designated as primary outcomes in a larger-scale study. The feasibility study was not designed to test the effectiveness of the hypothesis associated with any planned, main large-scale trial, and the sample size was very small. Nevertheless, there appeared to be a trend for certain cardiovascular health biomarkers after the REHIT intervention.

Primary results showed LDL decreased by 15.5±0.5 mg/dL and mean TC decreased by 16.5±2.5 mg/dL. There appeared to be no consistent trends in any of the other outcomes, including OGTT and MetS z-score (Table 2).

No further trends were identified, and therefore the data were analyzed per individual data (Table 3) to better understand the outcomes.

Oral glucose tolerance was reported as AUC. After the REHIT interventions, AUC increased by an average of 1.69%. If the data were analyzed per individual, subject one had a 14.42% decrease in AUC after REHIT intervention (Figure 3), and subject two had a 44.46% increase in AUC (Figure 4).

MetS z-score increased 0.26±1.70 after REHIT intervention. The average metabolic z-score after REHIT was -0.19, while at baseline it was -0.45. Analyzed per individual data, subject one improved MetS z-score from -0.99 to -1.93 post-REHIT intervention (Figure 5). Subject two noted an increase in MetS z-score from 0.09 to 1.55, indicating this subject was at greater risk for metabolic syndrome (Figure 6). As a whole, there was little to no change to metabolic syndrome z-score after REHIT intervention.

Table 1. Baseline Subject Characteristics.

Variable (n=2)	Mean ± SD
Age (years)	56 ± 2.2
Height (m)	1.63 ± 0.1
Weight (kg)	79.77 ± 26.7
BMI (Kg/m^2)	29.46 ± 7.38
RHR (bpm)	70.5 ± 5.5
SBP (mmHg)	146 ± 23
DBP (mmHg)	81 ± 4
WC (cm)	98.8 ± 14.2
LDL (mg/dL)	82 ± 26
TC (mg/dL)	153 ± 20
HDL (mg/dL)	55.5 ± 3.5
TRIG (mg/dL)	77 ± 13
BG (mg/dL)	98 ± 5
OGTT 1 (mg/dL)	203.5 ± 39.5
OGTT 2 (mg/dL)	208 ± 9.0
MetS Z-score	-0.45 ± 0.8
Vigorous Activity (min/wk)	75 ± 75
Moderate Activity (min/wk)	20 ± 0
Walking Activity (min/wk)	25 ± 25
Sitting time (hr/day)	11 ± 1

Abbreviations: BMI body mass index, RHR resting heart rate, SBP systolic blood pressure, DBP diastolic blood pressure, WC waist circumference, TRIG triglycerides, TC Total Cholesterol, BG blood glucose OGTT 1 oral glucose tolerance hour 1, OGTT 2 oral glucose tolerance hour 2, MetS z-score, metabolic syndrome severity.

Table 2. Mean change from baseline.

Measure	CONTROL (n=2)	REHIT (n=2)
Wt (kg)	-0.05 ± 2.47	0.33 ± 0.61
BMI (kg/m^2)	0.16 ± 0.34	0.14 ± 0.25
RHR (bpm)	-8 ± 3.54	7 ± 9.90
SBP (mmHg)	-13 ± 9.90	-5.5 ± 23.33
DBP (mmHg)	-7.5 ± 16.26	4 ± 7.07
WC (cm)	-2.75 ± 0.35	-3.84 ± 4.48
LDL (mg/dL)	-4 ± 25.45	-15.5 ± 0.5
TC (mg/dL)	-7 ± 31.11	-16.5 ± 2.5
HDL (mg/dL)	3.5 ± 0.71	1.5 ± 6.36
TRIG (mg/dL)	-6.5 ± 13.44	-13.5 ± 20.51
BG (mg/dL)	0.5 ± 14.85	14 ± 1.41
OGTT 1 (mg/dL)	4.5 ± 43.13	11.5 ± 37.48
OGTT 2 (mg/dL)	2.5 ± 51.6	18 ± 21.21
MetS z-score	-1.455 ± 0.36	0.26 ± 1.70

Note: Data are presented as mean ± standard deviations. A negative number represents a decrease after REHIT or control intervention. Abbreviations: WT weight, BMI body mass index, RHR resting heart rate, SBP systolic blood pressure, DBP diastolic blood pressure, WC waist circumference, TC Total cholesterol, TRIG triglycerides, BG fasted blood glucose, OGTT1 oral glucose tolerance first hour, OGTT2 oral glucose tolerance second hour.

Table 3. Individual subject measures, baseline, control, and REHIT.

	Subject 1			Subject 2		
	BASELINE	CONTROL	REHIT	BASELINE	CONTROL	REHIT
Height (m)	1.55	1.55	1.55	1.7	1.7	1.7
Weight (kg)	53.0	54.0	53.8	106.5	108.2	106.4
BMI (kg/m^2)	22.08	22.48	22.39	36.85	37.44	36.82
WC (cm)	84.67	81.67	84	113	110.5	106
RHR (bpm)	65	60	79	76	66	76
BP (mmhg)	162/78	142/82	140/77	130/83	124/64	141/92
HDL (mg/dL)	59	63	65	52	55	49
LDL (mg/dL)	56	70	41	108	86	92
Trig (mg/dL)	90	74	62	64	67	65
TC (mg/dL)	133	148	119	173	154	154
BG (mg/dL)	103	96	116	93	104	108
OGTT 1 (mg/dL)	243	217	228	164	199	202
OGTT 2 (mg/dL)	194	160	197	119	158	152

Abbreviations: BMI body mass index, WC waist circumference, RHR resting heart rate, BP systolic/diastolic, WC waist circumference, TC Total Cholesterol, TRIG triglycerides, BG fasted blood glucose, OGTT1 oral glucose tolerance first hour, OGTT2 oral glucose tolerance second hour.

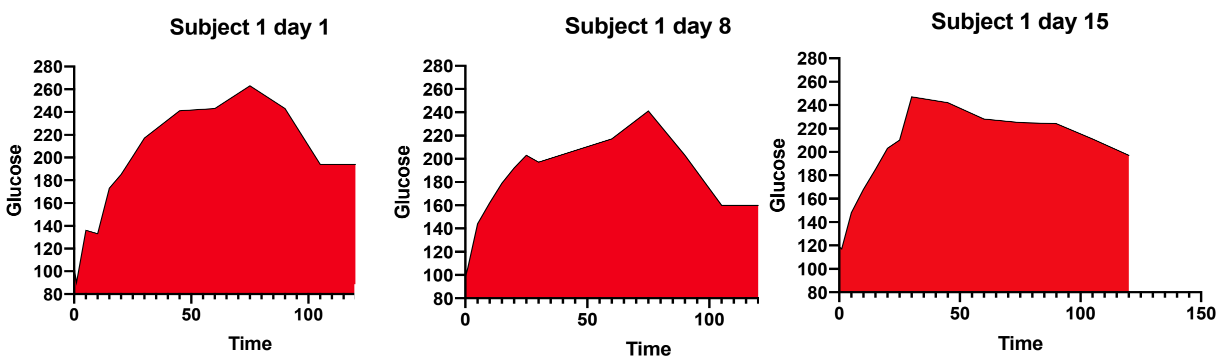

Figure 3. OGTT AUC for subject one, day 1 (baseline), day 8 (post control week), day 15 (post REHIT intervention).

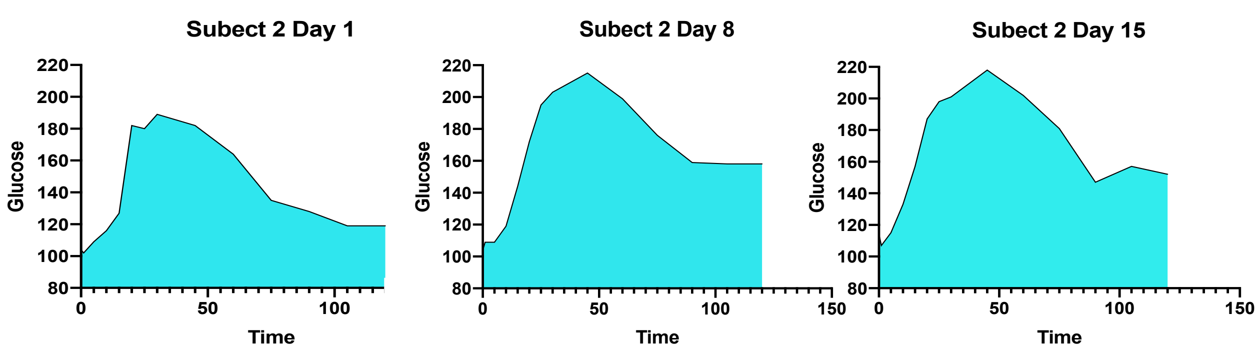

Figure 4. OGTT AUC for subject two, day 1 (baseline), day 8 (post control week), day 15 (post REHIT intervention).

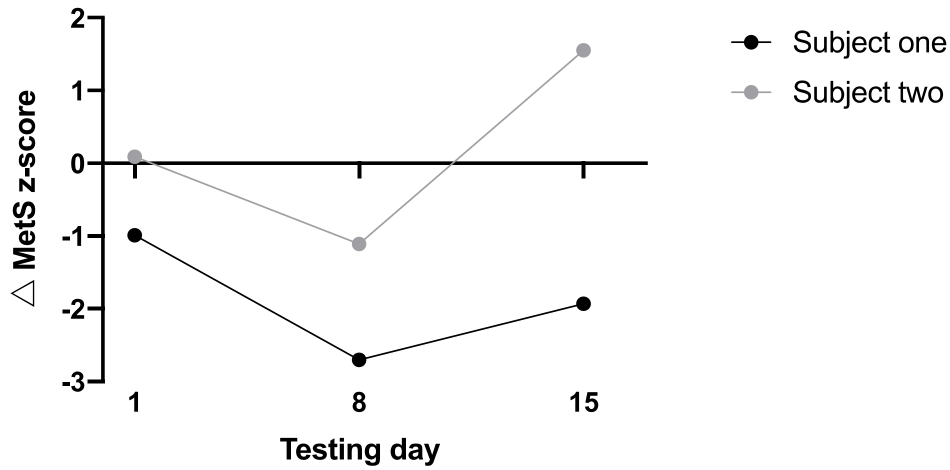

Figure 5. Metabolic syndrome severity z-score analyzed days 1, 8, and 15.

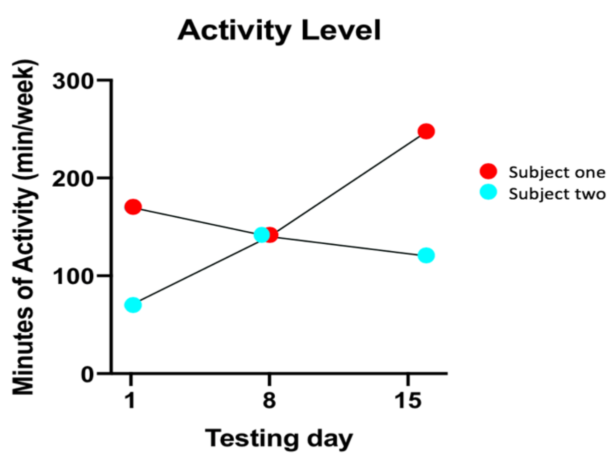

Figure 6. Activity level. Self-reported in total minutes per week of walking, moderate intensity, and vigorous intensity on days 1, 8, and 15.

Summary of progression criteria

Two of the three criteria for progression to a full-scale study were met. Notably, recruitment and retention rates (progression criterion 1) were deemed unlikely to be feasible, however, COVID-19 did affect this criterion. A large-scale study with this specific population may be more successful in a larger, more populous county, and/or not during a pandemic. The acceptability of the intervention (progression criterion two) did meet the criterion threshold and might be suitable in the current form for any future related studies. The outcomes (progression criterion 3) did show two trends in cardiometabolic health and did not show any other trends. However, these two metabolic factors could play a huge role in the overall health of the individuals and should be further evaluated and included in further studies.

DISCUSSION

The aims of this study were, (1) to investigate the effect of interrupting prolonged sedentary bouts with a daily REHIT, upper-body, aerobic session on cardiometabolic health measured by lipid profiles, glucose tolerance, BP, WC, and BMI in individuals who were sedentary due to a mobility disability, and (2) to determine the feasibility of implementing a REHIT program in this population. The findings revealed several issues relating to subject recruitment that would need to be considered to optimize the design and conduct of future, related studies. It was not possible, based on the data collected, to estimate variability for use in a formal sample size calculation for a future study. This reinforces the need to conduct a study during a time and in a location where the rate of eligible people, who are willing to participate, is in surplus. Similar feasibility studies have highlighted that physical activity interventions can be challenging due to recruitment, retention, and participant dropout issues[19]. However, this intervention may require a minimal amount of behavioral change, as such, advancing to a large-scale study may be appropriate because key progression criteria were met (two of three). Future research may benefit from this developmental proof of concept work.

Three participants underwent baseline testing and two commenced the exercise intervention. This occurred due to the COVID-19 pandemic, and may not have occurred otherwise. We also experienced a delay in data collection due to the need for approvals from multiple subjects' physical therapists (PT). Recruitment was limited due to the active population and inclement weather in the University's location, as this is not a desirable location for those in wheelchairs or with other physical disabilities. However, the reason for dropout, and those who declined to participate in the study, were not related to the intervention, or time commitment asked of the study.

Adherence to the exercise intervention was high and no adverse events were reported. The REHIT intervention was tolerable to both subjects, as 100% of total REHIT sessions were completed. We also saw self-reported moderate intensity activity increase after the REHIT intervention in both subjects. Vigorous activity was either increased or maintained after the REHIT intervention in the subjects from self-reported data. Incorporating the REHIT intervention added more activity to the subjects' lifestyles, while still maintaining what they were already doing. This is important because for REHIT to play any role in public health, it must be tolerable to those for whom it is intended, in this case, the sedentary disabled population.

Additionally, it is possible that the intervention volume was insufficient to elicit marked cardiometabolic change in the sample. The REHIT portion of the current study lasted one week whereas similar studies have seen beneficial cardiometabolic improvements after a longer intervention[16,17]. It is also likely that one, eight-minute REHIT bout per day was inadequate to show marked cardiometabolic improvements in the sample. Indeed, McCarthy et al. (2017) found improvement using a five-minute arm ergometry intervention every 30 minutes[12]. Finally, although this intervention was convenient and highly functional for the subjects, it is possible this intervention needed to be more standardized, as other REHIT studies used the CAROL high octane bike[15], or an arm ergometry machine[12] of which both modalities control for consistency and reduce human error more precisely. We did find that this intervention was ideal for retention. However, there was no way to monitor intensity and ensure subjects were giving their full effort, (beyond their subjective measure via RPE). Subjects one and two reported an overall vigorous and moderate intensity RPE to the intervention, respectively.

Lipid profile

A decrease in LDL, TC, and triglycerides and an increase in HDL are arguably the most important factors to decrease the risk of atherosclerosis and other heart disease complications because dyslipidemia has been suggested as a common denominator for hypertension, obesity, and impaired glucose tolerance[20]. In the current study, the observed reductions in TC were present with both a reduction in LDL and either an increase or no change in HDL. It should be mentioned that subjects started the study with healthy cholesterol levels. Therefore, it may seem trivial to note the change in cholesterol. However, as women age and estrogen declines, during and after menopause, TC and LDL increase and HDL decreases[21]. Estrogen acts as a regulator for cholesterol[22] and its decline post menopause factors into women's increased risk for CVD as they age[23]. Thus, as both subjects were past menopause they were at a heightened risk for CVD[23] and therefore reducing TC, LDL, and increasing HDL may stave off amplified risk with increasing age. In addition, the changes in cholesterol seen with increased movement in this study bode well concerning the feasibility of a similar intervention being beneficial for individuals with poor cholesterol profiles.

Experimental studies have interrupted prolonged sitting with REHIT, HIIT, walking breaks, and arm-ergometry breaks to elicit health benefits[11,12,15,24,25]. REHIT in able-bodied sedentary individuals, performed three times a week for three weeks, has been shown to decrease fasting blood glucose and HbA1c significantly and show a notable decrease in SBP and WC[16]. Additionally, a REHIT intervention of three exercise sessions a week for six weeks improved VO_2 peak and insulin sensitivity in abled-bodied individuals[15]. Improved insulin and glucose sensitivity were also seen in sedentary, obese, high-risk, able-bodied adults via five minutes of seated upper body activity every 30 minutes[12]. This proof of concept study did not identify a trend in glucose sensitivity or fasted blood glucose, but it should be noted that REHIT was performed just once a day, mirroring other REHIT protocols[15]. Based on the finding from McCarthy et al. (2017), to elicit changes in glucose sensitivity the intervention may need to be performed multiple times per day[12].

Oral Glucose Tolerance Test

The OGTT evaluates how the body manages glucose after a meal. Impaired glucose tolerance (IGT) is an important risk factor for numerous adverse health conditions and mortality and can be defined based on an abnormal OGTT. Ingesting meals rich in processed carbohydrates and saturated fat leads to exaggerated postprandial spikes in glucose and lipids. These spikes can promote oxidative stress which triggers inflammation, endothelial dysfunction, and sympathetic hyperactivity[26]. Individuals without diabetes but with an OGTT two-hour value of 140-199 mg/dL are considered to have IGT. Both subjects in this pilot study would fall into this category before and after the REHIT intervention. Those with IGT face a much greater risk of developing diabetes and CVD, emphasizing the importance of increasing physical activity and energy expenditure and decreasing sedentary time. Research is still needed in individuals with IGT using a REHIT intervention. It is important to note, OGTT results can be influenced by stress, illness, or medication. Indeed, OGTT is highly sensitive to stressors put on the body, as chronic and endocrine stress responses are significantly associated with glucose intolerance, insulin resistance, and diabetes mellitus[27]. OGTT AUC was the highest after the intervention in subject two, however, she subjectively reported being under a significant amount of stress on the last testing day. The COVID-19 pandemic notably impacted her work environment before her testing session, adding physical and mental stress. It is possible this dramatic rise in AUC for OGTT was due to a significant endocrine stress response to the pandemic.

Metabolic syndrome severity z-score

A z=0 coincides with the 50th percentile where approximately 50% of the population has a lower MetS severity score[28]. A more negative score is desirable. For instance, a z= -2 coincides with the 2nd percentile in MetS severity[28]. In this study, both subjects had a more negative number at baseline compared to post REHIT intervention. The most negative z-score was during the control week with an average z-score of -1.91±1.12. This suggests that the REHIT protocol in the present study did not improve MetS severity. Indeed, we did not see beneficial trends from REHIT intervention on HDL, triglycerides, fasting blood glucose, WC, or mean arterial pressure. Overall, there was little to no change to metabolic syndrome z-score after the REHIT intervention. There were, however, individual differences between subjects as seen in Tables 2 and 3.

Further research investigating the accurate threshold of physical activity in this specific population could aid in understanding the majority of this data. The threshold for physical activity may be higher considering this population does not partake in activities of daily living to the same extent as able-bodied individuals[29,30].

Limitations

Limitations to this study include a small sample size, recruiting in a county where disabled individuals do not often reside, and the COVID-19 pandemic. It may also be suggested to control for timing of physical activity more precisely, and control for intensity of the intervention more accurately. In addition, subjects were instructed to maintain their normal diets, activity, and sleep patterns but these were not directly measured. Finally, due to time constraints (owing to the imminent COVID-19 shut down) OGTT was measured the day after the last exercise session. This may have affected the results as those measurements may have reflected effects from the last exercise session and not the intervention itself. In future, taking these measures more than 48 hours after the last exercise session could provide more accurate data on the effects of the exercise intervention.

CONCLUSIONS

This study was designed and performed as a proof of concept study to determine the feasibility of this research as a larger scale study. Significant health benefits were not identified due to the limited sample size. However, two of the three criteria for progression to a full-scale study were met. Recruitment and retention rates (progression criterion 1) were deemed unfeasible, though it should be noted that COVID-19 and limited sample size did affect this criterion. Performing this study in a larger county that is more populous with the target population, and not during a pandemic, may result in more success. The accessibility of the intervention (progression criterion 2) did meet the criterion threshold and may be suitable in the current form for related future studies. The study outcomes (progression criterion 3) showed two trends in metabolic health (decreased TC and LDL) following REHIT intervention. No other trends were found, though it was noted that the most active week of the REHIT intervention had the greatest impact on cardiometabolic profile over the study. The outcomes of this study indicate that this is a feasible design for a future study. This research adds to a growing breadth of information regarding the potentially beneficial effects of exercise, primarily REHIT, in the sedentary and disabled population.

ADDRESS FOR CORRESPONDENCE

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