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Original Research

Utilizing Age-Predicted Heart Rate Maximum to Prescribe a Minimally Invasive Cycle Ergometer HIIT Protocol in Older Adults: A Feasibility Study

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ABSTRACT

International Journal of Exercise Science 15(4): 896-909, 2022. Previous research has provided evidence that aerobic HIIT exercise can induce important physiological adaptations and elicit improvements in health and fitness parameters. However, most of the research has taken place in a laboratory setting with specialized equipment and monitoring devices. It begs the question, is HIIT accessible to the general aging population? The objective of the current research was to employ an age-predicted HRmax to prescribe a minimally invasive 4x4 cycle ergometer HIIT protocol. Ten participants (age: 64.2 ± 6.1) completed a non-weight-bearing cycle ergometer protocol for 6 weeks. Significant Pearson correlations were found between %HRmax and W/kg in seven of the ten participants. Two participants showed significant correlations between RPE and W/kg. Half of the participants exhibited a significant correlation between %HRmax and RPE. Pre- to post-intervention measures demonstrated a significant increase in lower limb strength by the 10-repetition chair sit-to-stand (p = 0.004) and 30-second sit-to-stand (p = 0.021). Increased functional capacity demonstrated by TUG (p = 0.001) and SB (p = 0.034) also presented significant differences pre- to post-intervention. There was a 96% participant session completion rate. These data imply that a simple 4x4 cycle ergometer HIIT protocol prescribed using a %HRmax is effective at increasing lower-limb power/strength and can be used in the general older adult population without excessive oversight. Our intervention protocol demonstrates that 6 weeks of cycle ergometer HIIT is an adequate amount of time to result in lower limb strength and functional capacity improvements in active older adults.

KEYWORDS: High-intensity interval training, HR, rate of perceived exertion, RPE

INTRODUCTION

High-Intensity Interval Training (HIIT) is an exercise regimen that has been shown to induce important physiological adaptations and therefore elicit significant improvements in fitness and health (11). A typical session of HIIT consists of relatively brief bursts of vigorous physical activity (i.e. greater than 80% of aerobic capacity), interspersed with short rest periods of low-intensity physical activity (i.e. 50-60% of aerobic capacity) between intervals (9). A primary objective of HIIT is to maximize the efficiency of the exercise while minimizing the time investment (32). Therefore, HIIT can be considered a time-efficient training program since previous research has shown that the participants spend approximately 40% less time training than they would have in other types of exercise regimens (37). In addition, HIIT induces a greater adherence since many participants find it to be more enjoyable than other training methods (3). For that reason, HIIT avoids one of the greatest barriers to engaging in an exercise program: the "lack of time" (30).

HIIT has also been recognized as a suitable exercise regimen for patients diagnosed with chronic conditions such as cardiovascular diseases and diabetes due to its increased effect on cardiorespiratory fitness and metabolic function (13, 34). Some studies have reported that when compared with Moderate-Intensity Continues Training (MICT), HIIT has been shown to elicit superior improvements in indices of cardiorespiratory fitness (1, 13, 15, 29, 38). In addition, HIIT has improved memory in older adults and possibly avoided some age-related memory decline (20). Research has also determined that HIIT may be beneficial at reducing systolic blood pressure, improve body composition, decrease fall risk, and improve metabolic parameters (10, 14, 26, 38). A recently published systematic review by the authors of the current study found that HIIT was well-tolerated in an older population with significant, divergent comorbidities as well as being effective at increasing cardiorespiratory fitness (19). With that in mind, a study by Lee et al. found that cardiorespiratory fitness was more strongly associated with all-cause mortality than physical activity alone (22); therefore, although HIIT may elicit varying health benefits, improving cardiorespiratory fitness should be encouraged to reduce the risk of all-cause mortality and the current body of research is demonstrating that HIIT is beneficial at doing just that.

Additionally, while previous research suggests that HIIT is beneficial for older adults, much of that research has taken place in a clinical and/or laboratory setting with specialized equipment, monitoring devices (i.e., metabolic cart, graded exercise test, heart rate monitors, etc.), and substantial staff oversight. It begs the question, is HIIT accessible to the greater aging population outside of the research setting and without specialized equipment? Is HIIT a practical exercise protocol that can be utilized in the general older adult population without access to or adequate resources to pay for the appropriate supervision? An influential systematic review and meta-analysis by Weston, Wisloff, and Coombes (2014) indicate that more research needs to access the sustainability of an unsupervised HIIT program, one that would be encountered in a "real-world" setting, outside the clinical atmosphere (36). The current research builds upon a recently published systematic review and looks to explore the practicality and effectiveness of adding a minimally invasive HIIT protocol (2 days/week) to the weekly exercise regimen of active older adults.

Therefore, this research aimed to determine the feasibility of utilizing a cycle ergometer HIIT protocol prescribed solely with a percentage of age-predicted heart rate maximum (HRmax) in a community-based, minimally invasive exercise program. A secondary aim was to determine what effects this cycle ergometer HIIT protocol may have on strength, balance, and gait parameters in an active, older adult population. The researchers hypothesize that there will be strength, balance, and gait benefits of a minimally invasive, HRmax controlled, cycle ergometer HIIT protocol, without aggressive staff oversight or need for specialized equipment. The program's feasibility will be considered successful if the participants can complete the HIIT protocol with ≥ 80% completion rate and improvements are noted in any of the outcome variables observed in the research.

METHODS

Participants

A randomized control design including a HIIT intervention group, and a non-intervention control group were originally enrolled in the study. Due to the unexpected state of emergency enacted by the Spanish government regarding the Covid-19 pandemic, the authors could collect data from only a limited number of HIIT intervention participants that had already been scheduled for post-intervention measurements prior to the state of emergency and consequently the closure of the facilities. Therefore, the authors consider that these data serve as a feasibility study for enacting a minimally invasive HIIT intervention in an active aging population without aggressive oversight or equipment requirements.

Participants were recruited and screened according to the study inclusion/exclusion criteria. Randomization was based on a random number generator as well as the availability of the participants to complete the two additional HIIT interventions per week. Participants were instructed not to alter their diet, or their normal physical activity habits except for the scheduled exercise sessions of this study. Outcome assessments were performed at baseline and after the 6-week intervention. The same researchers performed the assessments at baseline and post-intervention while strictly adhering to the established standard operating procedures. Individual participant's data was coded to ensure blinding during data analysis.
The ethical recommendation approved in the Declaration of Helsinki (2013) was observed. In addition, we followed the instructions of the European Union on Good Clinical Practice (111/3976/88 of July 1990), as specified in a National legal framework for human clinical research (Royal Decree 561/1993 on clinical essays). The study was approved by the University Ethics Committee (Reference: NOV.19/5.TES).

Measurements: Study procedures and exercise training were performed at the local university's sports center. Baseline and post-intervention testing were performed as follows.

Anthropometrics: Participants wore light, exercise-type clothing and were assessed barefoot during this test; they were asked to wear the same or similar clothing for both the pre-and post-tests. Height was measured to the nearest millimeter using a stadiometer and an average of three measures was used. Bodyweight was measured to the nearest 0.1 kg using the InBody 270 bio-impedance analysis scale (InBody Co. Ltd. InBody Bldg., 625, Eonju-ro, Gangnam-gu, Seoul, 06106 Korea). Body mass index was calculated by taking the weight in kilograms divided by height in meters squared (kg/m^2).

Resting Blood Pressure (BP): BP and Heart Rate (HR) were measured over the brachial artery using an automated oscillometric device (Omron M2 - HHEM-7121-E, OMRON Healthcare Europe B.V. Scorpius 33, 2132 LR Hoofddorp, The Netherlands) while the participant was seated with both feet placed on the ground. For this study, the lowest of two measurements was used.

Lipids & Glucose: Fasting serum blood samples were analyzed by using a handheld device using standard procedures; total cholesterol levels were analyzed with the Accutrend® Plus System (Roche Diagnostics International AG, Forrenstrasse 26343, Rotkreuz, Switzerland) and glucose was analyzed with the Accu-Check® Aviva (Roche Diabetes Care Spain, S.L. Avda. de la Generalitat, 171-173. 08174 Sant Cugat del Vallès, Barcelona).

Upper body strength: We used a handgrip dynamometer to measure isometric grip force. Both the right- and left-hand grip forces were measured. Two measures were performed for each hand, and the highest value was used for statistical analysis. Complete recovery was allowed between attempts (16). We used the TKK.5101 adaptive manual pressure dynamometer, with a precision of 0.1 Kg, as used in previous studies (27).

Lower body strength was assessed through the different tests: 30-second Chair sit-to-stand (S-t-S): To conduct the test, we used a standard 42 cm chair without arms. The chair was situated against a wall to avoid any movement during the test. To start the test, the participant was seated on the chair, back straight, feet approximately shoulder-width apart, and placed on the floor at an angle slightly back from the knees. The test started at the signal of "ready, set, go", then the participant would rise to a full stand (body erect and straight) and then return to the seated position. They were encouraged verbally to complete as many full stands as possible in 30 seconds. The evaluator silently counted each correct stand. Before the participant began the test, the evaluator conducted a demonstration and a practical trial of 1-2 repetitions was allowed. The total number of repetitions executed properly was recorded per previous research (18).

10-repetition Chair S-t-S: Similarly, the 10-repetition chair S-t-S was conducted in the same way as the 30-second chair S-t-S. We recorded the time required to complete 10 full stands from the sitting position. We allowed one practice trial before starting the test to learn the task and perform it properly. The participants were encouraged to complete the test as quickly as possible (8).

Lower limb power was calculated using the method presented by Baltazar et al. (2). Using both the 30-second S-t-S and the 10 repetition S-t-S, we calculated power (watts). Mechanical Power (W) = Force x Velocity (see equation below)

$$\textbf{Estimated Power} = (BM \times 0.9 \times g) \times \frac{([Body\ h \times 0.5] - Chair\ h)}{\left(\frac{Total\ STS\ t}{n\ STS\ reps}\right) \times 0.5}$$

To measure gait, we used the OptoGait device (Microgate, Bolzano, Italy). It is an optical data acquisition system, composed of a transmitter and a receiver optical bar. Each bar contains 96 Infrared LEDs (1,041 cm resolution). These LEDs are located on the transmitter bar and communicate continuously with the LEDs located on the receiver bar. The system detects the eventual interruptions and their duration. It is a valid measurement device for the assessment of spatiotemporal gait parameters (23). The protocol used to carry out the test was 5 meters in which they had to walk within the walkway formed by the OptoGait. They made 6 roundtrip passes in which they had to walk comfortably at a normal pace, like that used in their everyday life. Participants started walking 2.5 meters before the start of the OptoGait system and turned around 2.5 meters from the end of the Optogait system. The total travel in each pass was 10 m, as the Optogait covers the 5 m in the center, where the measurement takes place. The variables that were considered in this research were step length (cm), coefficient of variation of step (%), and gait speed (m/s)

Static balance (SB): Measured in time (seconds). To perform the test, the participants must stand unassisted on one leg (dominant leg) with their arms folded across the chest. Time was recorded with a stopwatch and time started when the participant lifted one foot off the ground and stopped when that same foot touched the ground again or when the participant reached 60 seconds. The test was performed with eyes open and with tennis shoes. Before testing, the evaluator demonstrated the position to assume during the test (17).

Timed up & go (TUG): Measured in time (seconds) and reflects agility and dynamic balance. To complete this test, the participant started sitting and stood from a 42cm chair. After a countdown (ready, set, go), a timer was initiated, and the participant started the test. They were asked to rise from the seated position, walk at a self-selected pace toward a marker on the floor 3 meters away from the chair, turn around the marker, return to the chair and sit down again. Timing stopped when the participant sat back down in the chair (28).

Cardiorespiratory fitness: 6 Minute walk test measured in distance (m) was used to assess aerobic endurance. The original version of this test is included in the Senior Fitness Test which has exhibited high reliability (31). To complete the test, the participants walk for 6 minutes in a flat rectangular course (30 x 5 m) which is marked with a red line every 5 meters. Bright-colored cones were used to mark the four corners of the course which indicated to the participant the point at which they turn left. We assessed the participants in groups (between 3 to 6 participants) on the course at a given time, using staggered starting and stopping times to promote individual pacing and avoid walking together in groups or pairs. The participants were instructed to cover the maximum distance possible walking as fast as they comfortably could without running, and without overexerting or pushing themselves beyond their limits. Furthermore, the evaluators used encouragement phrases (e.g., You are doing well, keep up the good work, you can do it...) each time that the participants passed the starting point. We announced to the participants the time left approximately halfway through the test (3 min), 2 min left, and 1 min left respectively. When the time was complete, the evaluators announced the name of the participant and the word "stop". At this moment, the evaluator recorded the total distance completed by each participant to the nearest 5 meters.

Exercise Intervention: Subjects participated in a non-weight-bearing cycle ergometer (KOR M-9540 by Salter, Arias Montano 28, 28007 Madrid, Spain) HIIT exercise regimen 2 days/week for 6 weeks, under the supervision of an onsite exercise specialist who tracked the participant's heart rate (HR), rate of perceived exertion (RPE) and watt production during every interval of each exercise session. The objective of the onsite exercise specialist was notating outcome measures (HR, RPE, and watts) and help the participants in the case of an adverse event or specific questions regarding equipment and/or malfunctions. The intervention consisted of 4×4-minute intervals interspersed by 3×3-minute active recovery periods. The participants were given 85% of their heart rate maximum (HRmax) and were instructed to attain their respective values in the 4-minute HIIT intervals. A 5-minute warm-up at 60% of HRmax was included in each exercise session which amassed a total of 32 minutes of cycling.

HRmax was predicted applying the Tanaka method using 208 – 0.7 x age (33). Exercise HR was displayed and recorded during each exercise session using the cycle ergometers respective handheld heart rate telemetry system. Participants were instructed to reach target HR by modifying their cadence (increased cadence = increased HR, decreased cadence = decreased HR), if the adjustment of cadence was not adequate to elicit a rise or fall in HR the participants were advised to adjust the level of resistance accordingly. Due to the possibility that participants may have been unfamiliar with exercising on a cycle ergometer, a pre-conditioning period was completed before the 6-week intervention. The preconditioning sessions increased the individual's tolerated duration of exercise until the participants could perform 35 minutes of cycling at 70% of HRmax and they were familiar with the exercise equipment, at which point the participants started the 6-week HIIT intervention.

Statistical Analysis

Power analysis was performed with G*Power Version 3.1.9.4 using lower limb functional capacity (TUG and S-t-S) as the primary outcome measures. The sample size was calculated with $\alpha = 0.05$ and power = 0.70 with values between pre-and post-tests based on previous research (5, 24, 26). All variables are expressed as a mean and standard deviation (M ± SD) and were analyzed using the statistical package SPSS v. 27 (SPSS Inc., Chicago, IL, USA). Normality assumption by Shapiro–Wilks was identified for each variable of the paired samples. A paired sample's t-test was used to compare the pre- to post-intervention measures. Post hoc analysis was corrected using the Bonferroni adjustment. Significant differences were established at a p-value of < 0.05. Cohen's D was used to assess the magnitude of mean differences. A recent review of effect size in gerontology suggested the interpretation of effect sizes is small = 0.15, medium = 0.40, and large = 0.75 (4). Post analysis of % HRmax, RPE, and watts per kilogram of body mass (W/kg) for the average of all exercise sessions for each of the four intervals were analyzed using a general linear model within-subjects repeated measures. Individual participants' Pearson correlations were analyzed between %HRmax, RPE, and W/kg respectively.

RESULTS

The estimated marginal means for all exercise sessions of W/kg, %HRmax, and RPE by gender and total are presented in Table 1. W/kg remained consistent throughout the intervals although there was a slight rise from interval 1 to 4. Similarly, there was a documented rise of %HRmax alongside the increased effort of W/kg from intervals 1 to 4 from approximately 80% to 85%. Likewise, RPE showed a trivial yet progressive rise alongside W/kg from interval 1 to 4 as noted in Table 1.

Table 1. Estimated Marginal Means per Interval (mean ± standard deviation).

		Total (*N* = 10)	Males (*N* = 3)	Females (*N* = 7)
Interval 1	W/kg	1.14 ± 0.38	1.51 ± 0.35	0.98 ± 0.28
	%HRmax	79.70 ± 6.57	78.79 ± 6.96	80.09 ± 6.93
	RPE	12.11 ± 0.57	12.00 ± 0.34	12.16 ± 0.66
Interval 2	W/kg	1.18 ± 0.41	1.53 ± 0.47	1.02 ± 0.29
	%HRmax	82.75 ± 7.03	82.48 ± 8.00	82.87 ± 7.26
	RPE	12.67 ± 0.63	12.37 ± 0.77	12.80 ± 0.58
Interval 3	W/kg	1.20 ± 0.39	1.53 ± 0.41	1.06 ± 0.30
	%HRmax	82.96 ± 6.65	82.08 ± 7.90	83.34 ± 6.70
	RPE	12.67 ± 0.63	12.85 ± 0.79	12.59 ± 0.61
Interval 4	W/kg	1.24 ± 0.39	1.59 ± 0.41	1.09 ± 0.28
	%HRmax	84.82 ± 6.63	83.85 ± 7.15	85.23 ± 6.94
	RPE	13.11 ± 0.74	12.94 ± 0.92	13.19 ± 0.72

The individual participants' Pearson correlations of W/kg, %HRmax, and RPE throughout the intervention are presented in Table 2. Significant Pearson correlations were found between %HRmax and W/kg in seven of the ten participants. Only two participants had significant correlations between RPE and W/kg. Five of the ten participants demonstrated a significant correlation between %HRmax and RPE. The observation of all exercise sessions reveals a significant correlation between RPE and W/kg (r = 0.144) and %HRmax and RPE (r=0.155). Pearson correlation was not significant between %HRmax and W/kg when compared across all exercise sessions.

The participants lower limb strength demonstrated by the 10 repetition Sit-to-Stand (p = 0.004, Cohen's D = 0.660) and 30 second Sit-to-Stand (p = 0.021, Cohen's D = 0.635) displayed significant differences pre- to post-intervention. Likewise, the estimated calculated power of the 10 repetitions Sit-to-Stand (p = 0.005, Cohen's D = 0.494) exhibited a significant difference whereas the 30-second Sit-to-Stand bordered significance but not definitively (p = 0.05, Cohen's D = -0.662). Increased functional capacity demonstrated by TUG (p=0.001, Cohen's D = 0.940) and SB (p = 0.034, Cohen's D = 0.292) also presented significant differences pre- to post-intervention. No significant differences pre- to post-intervention were assessed for the other outcome measures reported in this study. Paired samples T-tests, effect size, and p-values in Table 3.

Table 2. Pearson Correlation for Individual Participants & Group Combined.

Participant		%HRmax – W/kg	RPE – W/kg	%HRmax - RPE
1	*r*	**0.523***	0.143	0.264
2	*r*	0.007	0.255	**0.396***
3	*r*	0.257	-0.010	0.322
4	*r*	**0.684***	-0.247	-0.029
5	*r*	**0.382***	0.144	**0.659****
6	*r*	**0.581****	**0.573****	**0.645****
7	*r*	0.183	-0.263	-0.283
8	*r*	**0.849****	0.250	**0.539****
9	*r*	**0.521***	0.358	0.147
10	*r*	**0.808****	**0.563****	**0.693****
ALL	*r*	0.065	**0.144***	**0.155***

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

Table 3. Paired Samples T-Test (mean ± standard deviation).

Variable	Pre-test	Post-test	Effect size†	*p*-value
Systolic BP (mmHg)	141.5 ± 12.8	137.6 ± 20.8	0.20	0.435
Diastolic BP (mmHg)	90.3 ± 5.3	87.6 ± 7.9	0.34	0.092
Resting Heart Rate (bpm)	78.2 ± 11.4	75.7 ± 10.7	0.23	0.296
Body Mass (kg)	77.3 ± 11.2	76.5 ± 10.3	0.05	0.099
Body Mass Index (kg/m^2)	29.2 ± 4.1	28.9 ± 3.9	0.06	0.106
Total Cholesterol (mg/dl)	211.4 ± 39.2	226.9 ± 33.7	0.42	0.169
Fasting Glucose (mg/dl)	99.22 ± 9.1	99.78 ± 6.2	0.07	0.855
Hand Grip (right) (kg)	28.1 ± 9.4	29.0 ± 11.2	0.08	0.463
Hand Grip (left) (kg)	26.0 ± 9.0	26.8 ± 10.3	0.07	0.405
10 rep S-t-S(s)	13.9 ± 3.0	11.9 ± 3.1	0.66	**0.004**
Power S-t-S (w)	206.2 ± 61.7	236.5 ± 51.3	0.49	**0.005**
30 sec. S-t-S(Rep)	18.0 ± 3.3	20.3 ± 3.9	0.64	**0.021**
Power 30 sec. S-t-S (w)	158.4 ± 27.0	177.0 ± 29.1	0.66	0.050
Timed Up and Go (s)	5.1± 0.5	4.5 ± 0.7	0.94	**0.001**
Complex Gait Test (s)	14.0 ± 2.4	14.1 ± 1.8	0.03	0.891
Static Balance (s)	30.4 ± 21.0	36.6 ± 21.5	0.29	**0.034**
6-Minute Walk (m)	624 ± 53.2	641 ± 62.8	0.28	0.121
Gait Velocity (m/s)	1.69 ± 0.17	1.64 ± 0.20	0.25	0.273
Step Length (cm)	75.83 ± 4.8	73.34 ± 5.3	0.49	0.124

† Cohen's D; S-t-S: Sit to Stand; bpm: beats per minute; W: watts: Rep: repetition.

DISCUSSION

This research aimed to determine the feasibility of prescribing a minimally invasive cycle ergometer HIIT protocol using a percentage of age-predicted HRmax to improve functional capacities. Although the target HR of 85% HRmax was not achieved, improvements in lower limb strength and balance were nevertheless significant. When examining the group means of W/kg, %HRmax, and RPE all data points demonstrated a steady rise from interval 1 to interval 4 with a small plateau between interval 2 and 3. Although these changes are small, they do reveal that when examined as a group mean all three variables incrementally change together which contributes to the idea that HR is a good indicator of work rate. This is demonstrated in Table 2 where the individual correlation between %HRmax and W/kg are correlated in seven of the ten participants.

Therefore, the authors believe that HR can be used to prescribe an unsupervised or minimally supervised cycle ergometer HIIT protocol in an older adult population. Using HR to prescribe HIIT can become even more practical when used in combination with RPE. However, it is necessary to caution that not every individual response is equivalent (i.e., 85% of HRmax is not always equal to an RPE of 13). At a given work rate, individual participants can demonstrate a higher %HRmax although their respective RPE is much lower or vice versa. This idea is supported by a study by Jabbour & Majed (2018) which determined that RPE alone may misclassify exercise intensity for sedentary older adults but that is nevertheless useful when used in combination with other commonly used methods such as %HRmax (18). When examining group data combined it appears that RPE is more closely correlated with W/kg. However, once again, it is necessary to use caution as the authors believe this is an erroneous approach to reviewing the data because it does not consider the individual's capacity for work (peak watts, functional threshold power, etc.). If the study had accounted for the maximum aerobic capacity of each participant, we could have then examined the correlation between %HRmax and a percentage of maximum aerobic capacity, which is a more valid comparison. Thus, while %HRmax was not correlated with W/kg in the grouped data of this study, it appears to be a more appropriate means to prescribe cycle ergometer exercise on an individual level. As mentioned earlier, the current data revealed that at the individual level, an increase in W/kg correlated with an increase in %HRmax in seven of the ten participants.

The authors believe that the feasibility of implementing a HIIT protocol in older adults using a simple calculation of %HRmax is justified, and further research can use this method of prescribing exercise in older adults. Although the prescribed intensity of 85% of HRmax was not met in all the intervals, they were not far below the mark and when examining the mean of all intervals combined it is equal to approximately 83% of HRmax. To put that into context, the average target HR (85% of maximum) for the current participants was 138 bpm, 135 bpm was the average recorded HR to equal the approximation of 83% of HRmax. A percentage of 82% of HRmax is still well within the range of what would be considered HIIT and/or vigorous exercise (6,36).

Though it is not comfortable to engage in HIIT exercise, once a participant understands their respective aerobic capacity (in this case, %HRmax) they often self-regulate their interval intensities without the need of an exercise specialist or other onsite observer. The current study maintained one exercise specialist per three HIIT participants; the authors consider this to be an appropriate 1:3 working ratio to maintain suitable oversight in the beginning stages of a HIIT protocol when the exercise specialist is needed the most to resolve any problems that may arise or questions that may need to be addressed. No specialized equipment was used in the current study and a simple, commercially available, cycle ergometer with power (watts), cadence (rpm), and a handheld heart rate sensor (bpm) was all that was needed to complete the 4x4 HIIT protocol. The authors of the current research trust that appropriately informed older adults can easily participate in cycle ergometer HIIT with minimum oversight from an exercise specialist and minimal amounts of specialized equipment. The authors would like to reiterate that the exercise specialist was not present to control the exercise intensities of the individual participants but rather track/report the intensities, encourage, and help participants in the case of an adverse event.

A secondary aim was to determine the effects that cycle ergometer HIIT training may have on parameters such as strength, balance, and gait in an already active, older adult population. The researchers hypothesized that there would be an added benefit to including minimally invasive HIIT to the exercise regimen of these active older adults. This research demonstrates that the authors' hypothesis was correct in that 6 weeks of cycle ergometer HIIT is an adequate amount of time to result in lower limb functional capacity and strength improvements in an active, non-clinical population of older/aging adults. This data is corroborated by research from Herrod, Lund, & Phillips (2021) which demonstrated positive health adaptations with just 6-weeks of cycle ergometer HIIT exercise (14). Therefore, the authors believe that these data are aligned with the literature in that 6-weeks of cycle ergometer HIIT is an adequate time to see significant improvements in health parameters such as balance, strength, and functional capacity.

Perhaps the most notable change witnessed in the participants was their lower limb power measures in both the 10 repetition sit-to-stand and the 30-second sit-to-stand. As noted in previous studies, loss of muscle mass and strength is common among older adults, which in turn decreases lower-limb function and therefore autonomy (7, 12, 21). The authors would like to repeat that one inclusion criteria for participation in the study was to be active in the multi-component group exercise class for longer than 6 months and many of the participants had been active for much longer (2-3 years on average). Therefore, the authors strongly believe that the lower limb strength was due to the adaptation from the HIIT training rather than the multi-component group exercise class. To the best of our knowledge, to date, there is no aerobic HIIT intervention that has demonstrated this type of positive increase in the S-t-S measurements and calculated power in watts. However, recently published research by Marzuca-Nassr et al. (2020) found that 12-weeks of cycle ergometer HIIT increased 1 repetition maximum for dominant leg strength (26). Likewise, Research by Vogel et al. indicated that with 9 weeks of aerobic cycling HIIT, participants had a greater maximum tolerance of power from baseline measures; suggesting that there may have been some muscular adaptation to allow for this increased tolerance (35). The authors of the current research highly recommend that future aerobic HIIT investigations in older adults report lower-limb power measures such as the chair sit-to-stand and TUG as they are easy to include, accessible to most research scenarios, and require minimal equipment.

Of the 115 total training sessions completed by the participants, not one resulted in an adverse event. The biggest complaint from the participants was related to the comfort of the seat on the cycle ergometer. As mentioned above, 115 total training sessions were completed out of a possible 120 which resulted in a 96% session completion rate. The training sessions not completed were reported as an unrelated illness or scheduling conflict.

The current research is just another study demonstrating that HIIT is a safe and effective means of participating in cardiovascular exercise, as not one participant presented an adverse event throughout the intervention. Our claim that HIIT is safe, is aligned with recent data reported in systematic reviews, a meta-analysis, as well as other previously published research (1, 10, 13, 19, 25). Not only does HIIT seem to be safe but also effective at engaging participants that would otherwise drop out of moderate-intensity continuous training (MICT) exercise routines. The participants of the current research often reported to the onsite exercise specialists that they enjoyed the challenge of the HIIT intervals and that the change in pace often made the exercise session time feel shorter than it actually was. These types of reports (although anecdotal), as well as other factors, may be contributing to the high completion rates that are seen with aerobic HIIT interventions. More research should assess the completion rates of various exercise interventions for longer periods and determine if there is a statistically significant difference amongst varying exercise interventions.

Limitations: The authors acknowledge that the current research has its limitations that need to be addressed. The central limitation of this data is the lack of a control group. The current research, like others, was affected by the Covid-19 pandemic and after a government-enforced shutdown, we could no longer access the control (nor the remaining HIIT) participants, thus no comparison group. However, due to the significant increase in lower limb strength and the large effect sizes, the authors believe the data merit further research. A secondary limitation is the small sample size of only 10 individuals, which in turn, limits our statistical power and increases the chance of type II error. Future research should examine larger samples of older adults from a variety of populations to determine the effectiveness of utilizing a %HRmax prescribed cycle ergometer exercise program without aggressive oversight to determine if HIIT is a practical exercise protocol to recommend in the general population.

Practical applications: The value of this research is that it indicates two practical applications for an aerobic cycle ergometer HIIT protocol. The first and most exciting for the authors is that aerobic HIIT can be applied outside of a clinical setting with little need for special equipment or oversight from an exercise specialist. The current research used a common cycle ergometer that can be found in most fitness centers/workout facilities, and we used a simple maximum heart rate calculation to determine the prescribed interval intensities. Once the participant established an understanding of the protocol they could and would often be self-sufficient; at times even reminding the onsite exercise specialist when their intervals were beginning and/or ending to log the participant's data.

A secondary application is the usefulness of an aerobic cycle ergometer HIIT protocol to not only have cardiorespiratory benefits, as noted in the current body of evidence but also appears to improve lower limb strength and functional capacity in older adults. The current study helps fill some gaps in the research regarding the effect that cycle ergometer HIIT may have on lower limb strength, gait, and balance parameters. The authors believe that although this data has its limitations and more research is needed, it also strengthens the idea that aerobic cycling HIIT improves functional capacities that may be capable of preventing falls and improving quality of life in older adults.

Conclusion: Although it is not possible to draw definitive conclusions from this data due to the lack of a control and/or comparison group, these data imply that a simple 4x4 cycle ergometer HIIT protocol can be prescribed to a broader, non-clinical population of older adults by using HRmax and using RPE as a guide in an unsupervised fashion. This study also demonstrates that 6 weeks of cycle ergometer HIIT is an adequate amount of time to result in lower limb strength and functional capacity improvements in active older adults. More research is warranted to determine the effects that cycle ergometer HIIT has on strength, balance, and gait parameters in older adults.

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