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Original Research

Comparison of Acute Cardiometabolic Responses in a 7-Minute Body Weight Circuit to 7-Minute HIIT Training Protocol

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ABSTRACT

International Journal of Exercise Science 13(2): 395-409, 2020. To investigate the acute cardiometabolic responses of a 7-minute bodyweight resistance exercise circuit (HICE) compared to a 7-minute high intensity interval training cycle protocol (HIIE). Methods: Twelve apparently healthy and active young adults were enrolled in a randomized crossover study (HICE *vs* HIIE). The 12 HICE exercises used a 30:5 second exercise to rest ratio, followed by a 3-minute cool-down and was replicated in the HIIE cycle protocol. Following each protocol, subjects were seated for the next hour. Measurements included blood pressure (BP) heart rate, blood glucose and triglycerides, taken prior to exercise, immediately after, 15, 30, 45, and 60-minutes post-exercise. Blood glucose and triglycerides were only taken, immediately after and at 60-minutes. General mixed linear modeling was used to analyze the data and Cohen's *d* was calculated for effect size. *Post hoc* analysis of individual time points used Bonferroni adjustment. Results: There was no significant difference in overall systolic BP between HIIE and HICE ($p = 0.168$). However, there was a significant difference in overall diastolic BP resulting a higher response in HIIE ($p = 0.002$). Immediately after exercise exhibited significant ($p = 0.001$) and trending, respectfully, higher values in diastolic BP for HIIE. The overall post-exercise heart rate was lower for HIIE *vs* HICE ($p < 0.001$). Blood glucose and Triglycerides had no overall difference between the two protocols ($p = 0.104$). Conclusion: The HICE protocol had a similar cardiometabolic response post-exercise to HIIE but did have a reduction in diastolic BP post-exercise. However, post-exercise heart rate was higher.

KEY WORDS: Exercise training, resistance training, brief activity bout, post-exercise hypotension, high-intensity interval training

INTRODUCTION

Less than optimal cardiometabolic health status is linked to the development of various health issues including cardiovascular disease, diabetes, and premature death (15, 24). Risk factors associated with these health outcomes include increased heart rate (HR), blood pressure (BP), blood glucose levels, and blood triglyceride levels (33). Management of these risk factors can improve health status and lower risk for the development of cardiovascular disease, diabetes, and premature death. Interestingly, one method of management of these risk factors includes engagement in structured exercise (2, 32) and those who participate regularly, have benefits that include but not limited to, reduction in resting HR, BP, better control of blood glucose and blood triglycerides (1).

Due to the beneficial impact of exercise, the American College of Sports Medicine (ACSM) and American Heart Association (AHA) established recommendations to assist in maintaining a healthy lifestyle by achieving a total of at least 30 minutes of moderate intensity aerobic exercise in 5 $d \cdot wk^{-1}$ or a total of 20 minutes of vigorous intensity aerobic exercise in 3 $d \cdot wk^{-1}$. Also, it is recommended to engage in activities that include muscular strength and endurance at least 2 $d \cdot wk^{-1}$ comprised of 8 to 10 exercises utilizing major muscle groups (16). Additionally, the recommendation allows for the accumulation of those minutes in any duration, allowing short bouts of activity to count towards meeting the recommended levels. Though achievable, these guidelines could propose barriers for individuals with busy schedules and may require monetary input for individuals, such as purchasing a gym membership, to meet these recommendations. Furthermore, barriers could include lack of time, accessibility, weather, occupation, safety, and lack of equipment (10, 18, 27, 45). These barriers hinder the ability for individuals to engage in exercise, and potentially play a role in only 19% women, 26% men, and 20% adolescents of the US population meeting ACSM and AHA guidelines (35).

Due to this lower participation, it is imperative for the continuing development of strategies and plans to help individuals engage in exercise. One barrier to exercise, lack of time, can be countered with exercise protocols that are short in duration but still provide meaningful benefit to an individual's health status (11, 21, 29). This has given rise over the past 10-20 years of utilizing high intensity interval training (HIIT) to achieve these benefits in short durations. Research has demonstrated that utilizing HIIT protocols compared to continuous running or cycling displays a similar and sometimes greater benefit to various risk factors including HR, BP, blood glucose, and blood triglycerides (5, 6, 12, 19, 30, 31, 36). Additionally, utilizing HIIT protocols significantly reduces time needed to exercise, cutting down to 10-15 min from 30-60 min timeframes typically seen in continuous aerobic activity. However, the majority of HIIT protocols would still require equipment or gym membership to complete as they are typically completed on a cycle or treadmill.

Fortunately, with the emergence of phone applications (commonly referred to as apps), users have the ability to be guided through exercise programming in any setting at no to minimal costs. One such app called "7-Minute Workout Challenge", consists of a HIIT-styled protocol incorporating resistance training using body weight exercises (22). The exercise plan contains brief bouts of intense exercise followed by a resting interval similar to a standard HIIT protocol such as cycling or running. Convenient for individuals who lack access to facilities and equipment, this app only requires minimal equipment that is found in a home such as a chair or step.

However, not many studies have assessed how affective a 7-minute bout of exercise is beneficial. One study examined acute responses comparing the 7-minute body weight exercise to a 7-minute HIIT protocol resulted in a higher rating of perceived exertion, Peak VO_2, and HR in the HIIT exercise but, had similar lactate concentration (39). In another study, healthy participants engaged in a 7-minute exercise on a regular basis for six weeks resulted in a slight decrease in waist circumference and body fat percentage (28). A study in recreationally active college students engaged in the 7-minute body weight circuit for eight weeks, three times per week and resulted in improved muscular strength and endurance (43). Yet, studies are lacking cardiometabolic responses such as HR, BP, blood glucose, and triglycerides.

Therefore, the purpose of this study was to investigate the acute cardiometabolic responses after a 7-minute bodyweight circuit compared to a 7-minute high intensity interval training protocol on a cycle. The primary aim was to compare the glucose and triglyceride response between conditions. Furthermore, we aimed to compare HR and BP between conditions. We hypothesized that high intensity circuit exercise (HICE) will cause a greater reduction to post-exercise BP, HR, blood glucose, and blood triglycerides than high intensity interval exercise (HIIE).

METHODS

Participants

Twelve (6 males and 6 females) apparently healthy and young adults ages ranged from 20-35 yr were recruited by promotional flyers and various classroom announcements from the city of Kingsville, TX and Texas A&M University-Kingsville. An informed consent was issued prior to participation of the requirements of the study, with risks and benefits fully explained prior to agreeing to participate. All subjects signed an informed consent and underwent a health screening according to the ACSM's guidelines for exercise testing and prescription (1). Only subjects cleared to engage in moderate-to-vigorous intensity exercise based on these guidelines were allowed to participate. The participants were excluded if they were diagnosed with a chronic condition that includes cardiovascular, metabolic, or renal diseases. Also, they were excluded if any participants were currently pregnant/planning on becoming pregnant during the duration of the study or has suffered from a current musculoskeletal injury. This research was carried out fully in accordance to the ethical standards of the *International Journal of Exercise Science* (34). The study was approved by the Institutional Review Board at Texas A&M University – Kingsville (12244/2018-073).

Protocol

The overall study design included a screening visit, followed by two experimental visits in random order utilizing a crossover design (Figure 1). Each experimental day was separated by a minimum of 7 d. Figure 2 depicts experimental visits, study progression, and further details explained below.

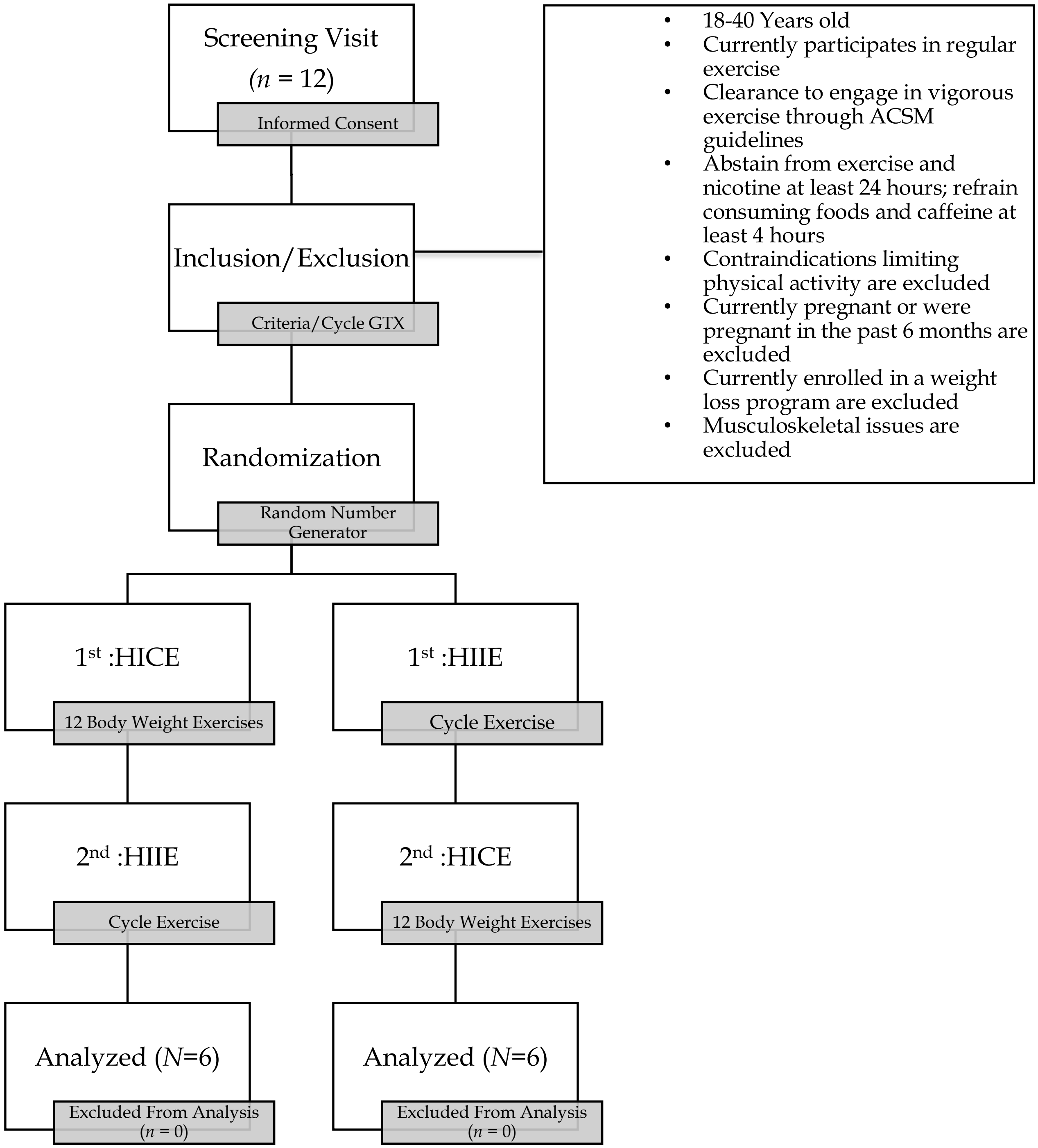

Figure 1. CONSORT diagram.

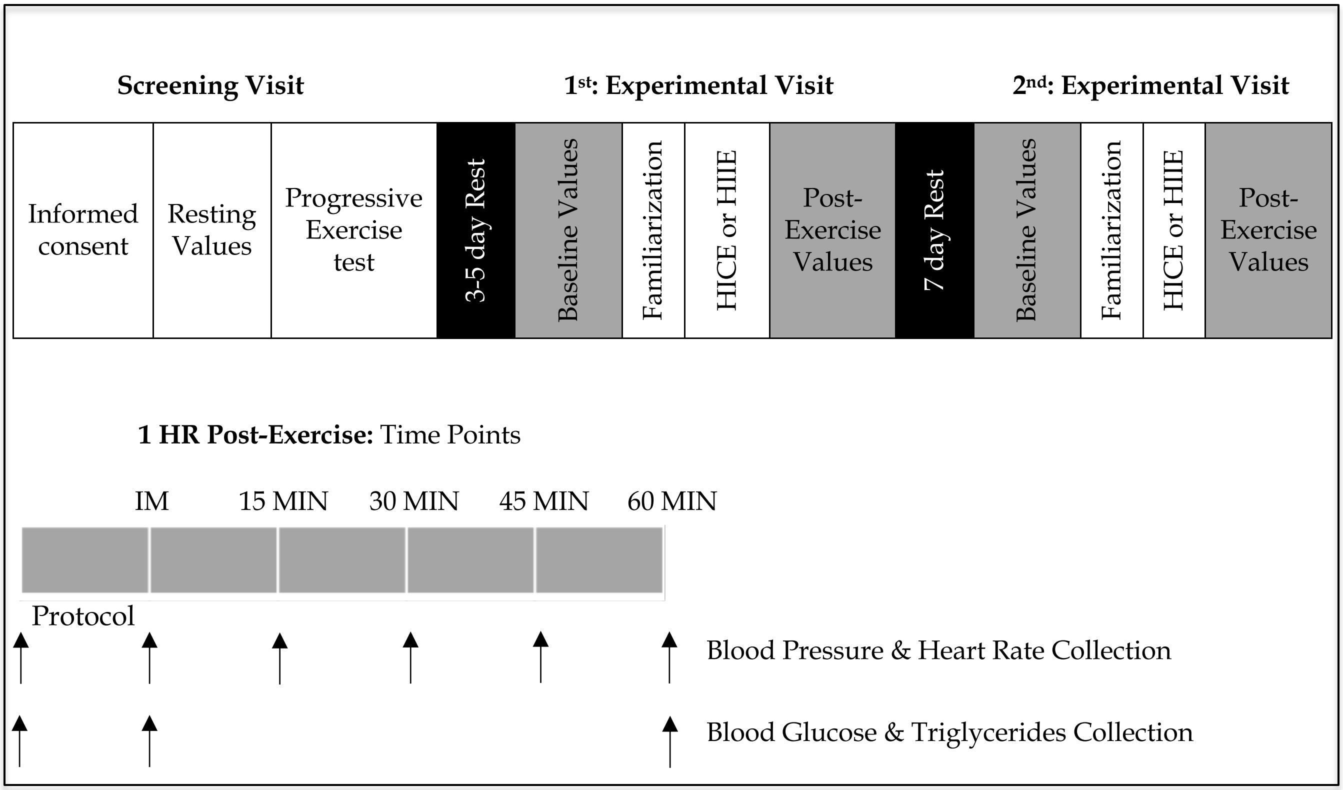

Figure 2. (Top) Overall study progression. (Bottom) post-exercise data collection. (IM = Immediately post-exercise).

Screening Visit: Following initial verbal interest, participants reported to the lab while abstaining from food and caffeine for at least 4 hr, and exercise and nicotine for 24 hr prior to the initial screening visit and experimental visits (verbally confirmed). During the initial visit, participants completed the informed consent. Following the consent, participants underwent a brief health history screening to determine eligibility. Additionally, they were assessed for characteristic information including height, weight, age, race, resting BP, and resting HR. Height and weight were obtained by using a wall-mounted stadiometer and a physician's beam scale. Resting HR and BP were measured utilizing an automatic device (Omron HEM-705, Lake Forest, IL). Participants rested in a seated posture approximately 10 min prior to the collection of both resting HR and BP measurements. Following resting measurements, participants engaged in an incremental exercise test on a rate independent cycle ergometer (Lode Corival, Groningen, Netherlands) to determine the appropriate power output (W) which elicited a heart range response of 70-80% of HRmax (220-age). This was used during the HIIE experimental visit. The incremental exercise test began at 70 rpm at 25 W and increased by 20 W for female and 25 W for males every 3 min until the participant's HR was within 70%-80% HRmax. A telemetric HR monitor (Polar, Bethpage, NY) was used to monitor HR continuously throughout the incremental exercise. Once the desired HR was achieved, participants went through a standardized cool down procedure that gradually reduced intensity to return the individual back to a resting state. The participants were then randomly assigned to perform either the HICE or HIIE on visiting days 2 and 3. Participants were instructed to consume the exact same meals on each of their experimental visits. Each testing session took place roughly at the same time point during the day (morning *vs* afternoon) to avoid any diurnal variation in measurements.

HICE: Once participants reported to the lab, they were seated on a chair to rest for 10 min prior to obtain measurements of BP, HR, blood glucose, and blood triglycerides measures for baseline values. Then, a brief familiarization session was demonstrated by the researchers for each of the 12 exercises as well as an explanation of how the 30 seconds of exercise paired with 5 seconds of rest/transition would transpire. This walk through of different stations ensured understanding for the participants as well as helped to minimize any time wasted during transitions. A mat and a 16-in step platform were set up for certain body weight exercises. All exercises were conducted in one area of the lab to minimize movement during transitions. The exercises were completed in the following order: 1) jumping jacks; 2) wall sits; 3) push-ups; 4) abdominal crunches; 5) step ups (on 16-in step); 6) squats; 7) triceps dips on step; 8) planks (high or low); 9) high knees; 10) lunges; 11) push-up with rotation (one hand points towards ceiling after up phase of push up and returns to the mat); and 12) side planks. The pace of each exercise was standardized utilizing a metronome. Participants received verbal encouragement when they were off tempo or unable to maintain proper technique to ensure compliance with protocol. At the end of each exercise HR was measured (30-second mark). Following the 7-min exercise session, the participants had a 3-min cool-down on a cycle ergometer at 50 rpm with a power output of 25 W, where HR was measured at the halfway mark and the end of the 3-min cool-down to ensure the participant's return to rest. Following the cool-down, the participants were moved to a chair and post-exercise measurements of BP and HR were assessed at immediately post-exercise, 15, 30, 45, and 60 min post-exercise. Blood glucose and triglycerides were assessed immediately post-exercise and 60 min post-exercise. Glucose and triglycerides were restricted in the number of collections in an effort to minimize participant burden.

HIIE: The participants reported to the lab and underwent identical baseline assessment as the HICE visit. Following baseline assessments, a short familiarization consisted of explaining to the participants the cycle ergometer protocol. The protocol utilized a similar time pattern as HICE (cycling of 30 sec exercise: 5 sec rest for 7 min). The participant cycled at 70 rpm at their predetermined power output (from screening visit) that elicited a HR response of 70-80% HR max for 30 sec followed by a 5-sec pause. A cadence was set at 140 bpm using a metronome to yield a pedal rate of 70 rpm assisting the participant to stay on tempo. The participants were instructed to stop pedaling after the 30-sec mark and their HR was recorded while resting for 5 sec. Following the 7-min exercise bout, the participants engaged in a similar cool-down as the HICE visit by cycling for 3 min during at 50 rpm with a power output of 25W, where HR was measured similar to the HICE protocol's cool-down. Following the cool-down all variables were measured up to 60 min post-exercise as described in the HICE protocol.

Procedures for data collection: The participants were measured for resting and post-exercise HR and BP using an automatic BP cuff (Omron HEM-705) with a size-appropriate cuff. Blood glucose and triglycerides were measured utilizing serum blood drawn via finger-stick and analyzed using the Alere Cholestech LDX (Abbott Park, IL) analyzer, a widely used point-of-care system. Blood (40 μL) was collected using a heparin-coated capillary tube and transferred to cassettes that were inserted into the device for analysis. Preparation of finger stick sites and cleanup of materials followed standardized procedures for this method.

Statistical Analysis
All data analysis was performed in Stata 15 (StataCorp, LP, College Station, Texas). Level of significance was set at $\alpha = 0.05$. Participant characteristics were summarized and reported as means $\pm$ standard deviations or by percentages. Total AUC was calculated for both glucose and triglycerides using the trapezoidal method to compare across conditions. A sensitivity analysis was also performed using net incremental AUC. Generalized mixed linear models was used to analyze impact of conditions (HICE *vs* HIIE) for the data. Time-by-condition interactions were checked for first, and when appropriate, controlled for time, condition order, sex, age, and baseline value. If no interaction was present, similar covariates were used. *Post-hoc* assessment of individual time points was also completed utilizing Bonferroni adjustment for multiple comparisons at each time point.

RESULTS

All participants completed both protocols and were included in the data analysis. All participant demographics are reported in Table 1.

Table 1. Participant Demographics.

Characteristic	Mean ± SD or N, %	Characteristic, cont.	Mean ± SD or N, %
Age, years	24.0 ± 4.3	Systolic Blood Pressure, mmHg	114.4 ± 7.4
Sex, Male/Female	6, 50%/6, 50%	Diastolic Blood Pressure, mmHg	67.0 ± 6.2
Height, cm	166.6 ± 6.2	Heart Rate, bpm	62.3 ± 6.4
Weight, kg	78.4 ± 14.1	Blood Glucose, mmol	4.96 ± 0.39
Body Mass Index, kg/m²	28.1 ± 6.4	Blood Triglyceride, mmol	4.65 ± 2.03

Comparison of overall BP displayed no significant differences between HIIE and HICE for SBP ($\beta = 1.639$ mmHg, $p = 0.168$, $d = 0.213$) as well as *post hoc* time point comparisons ($p > 0.05$) (Figure 3B). Interestingly, there was a significant difference in overall DBP in HIIE resulting in a higher response than HICE ($\beta = 2.273$ mmHg, $p = 0.002$, $d = 0.436$). A *post hoc* analysis with Bonferroni adjustment of individual time points exhibited a significant difference in DBP immediately after exercise resulting higher values in HIIE ($\beta = 5.018$ mmHg, $p = 0.001$, $d = 0.962$) (Figure 3C).

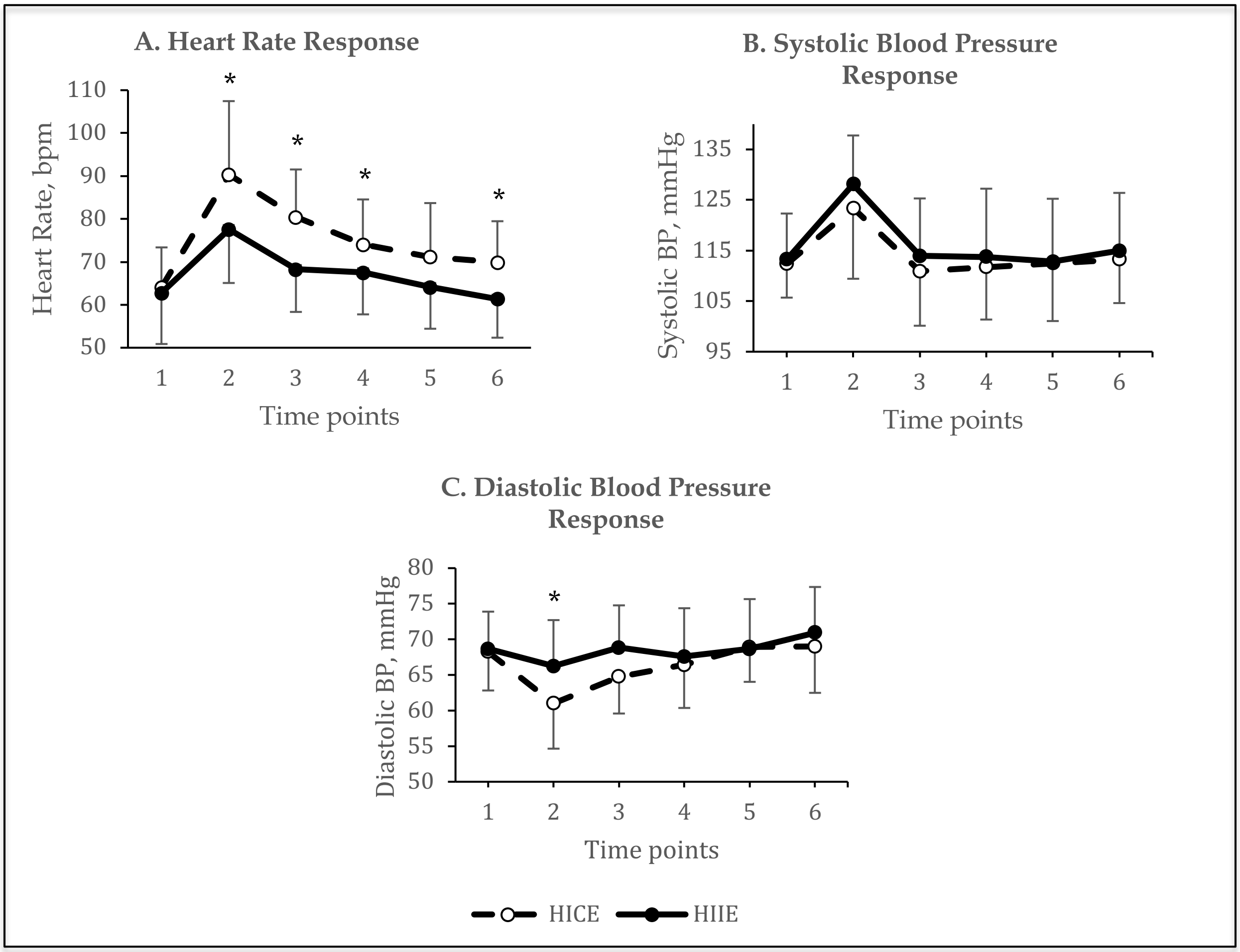

Figure 3. Heart Rate (A) and Blood Pressure (B, C) response post exercise for HICE *vs* HIIE.
Timepoints: 1) Rest, 2) IM, 3) 15-minutes, 4) 30-minutes, 5) 45-minutes, 6) 60-minutes
A) Overall effect on heart rate: β = -8.955 bpm, $p < 0.001$, d = 0.857
B) Overall effect on systolic blood pressure: β = 1.639 mmHg, p = 0.168, d = 0.213
C) Overall effect on diastolic blood pressure: β = 2.273 mmHg, p = 0.002, d = 0.436
* Indicates a significant difference at this time point between HICE and HIIE at $p < 0.01$

Overall, HR was significantly lower for HIIE compared to HICE (β = -8.955 bpm, $p < 0.001$, d = 0.857). *Post hoc* analysis with Bonferroni adjustment for each time point exhibited a significant lower response for HIIE at immediately after exercise (β = -11.791 bpm, $p < 0.001$, d = 1.128), 15-min after (β = -11.561 bpm, $p < 0.001$, d = 1.106), 30-min after (β = -5.737 bpm, $p < 0.001$, d = 0.549), and 60-min after (β = -7.664 bpm, $p < 0.001$, d = 0.733). There was no significant difference at time point 45-min after exercise between both protocols (Bonferroni adjustment p = 0.022). The HR response demonstrates an elevated post-exercise HR in HICE (Figure 3A), however, this could be potentially due to the significantly higher HR response during activity (HICE HRavg: 145.2 ± 16.9 bpm; HIIE HRavg: 126.3 ± 12.1 bpm, p = 0.005).

There was no significant difference between HIIE and HICE in overall blood glucose response (β = -0.200 mmol·L^{-1}, p = 0.104, d = 0.480). However, *post hoc* analysis exhibited a significant difference at time point immediately after exercise resulting in a lower blood glucose values for HIIE (β = -0.388 mmol·L^{-1}, p = 0.012, d = 0.930) (Figure 4). There was no significant difference in overall blood triglycerides response (HIIE *vs* HICE) (β = 0.014 mmol·L^{-1}, p = 0.966, d = 0.007) and in each time point post-exercise (p > 0.05).

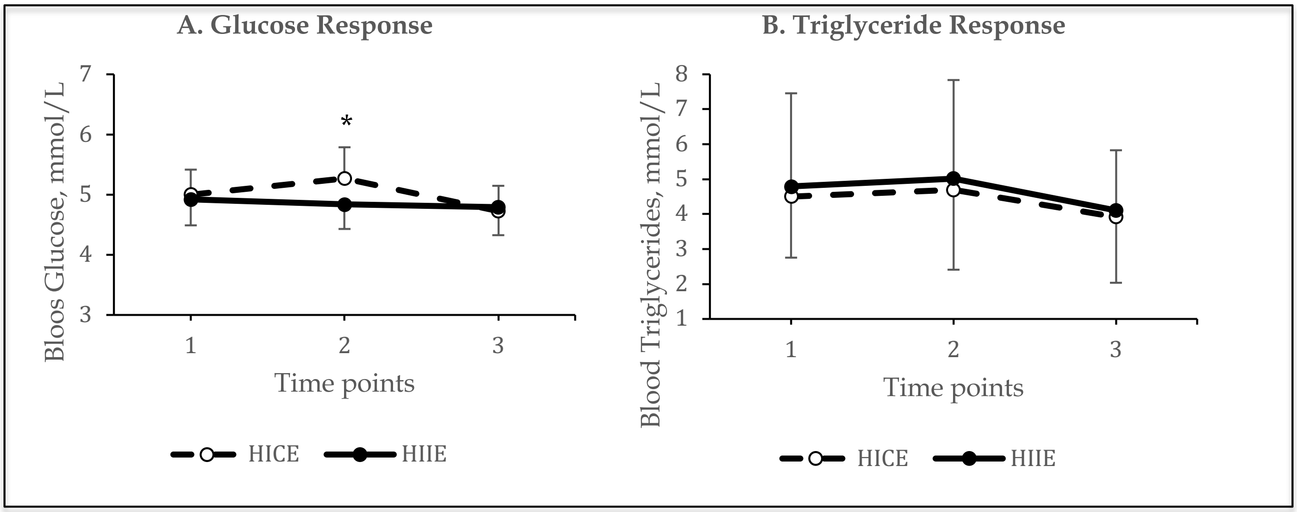

Figure 4. Blood Glucose (A) and Triglycerides (B) response post exercise for HICE *vs* HIIE.
A) Overall effect on blood glucose: β = -0.200 mmol/L, p = 0.104, d = 0.480
B) Overall effect on blood triglycerides: β = 0.014 mmol/L, p = 0.966, d = 0.007
* Indicates a significant difference at this time point between HICE and HIIE at p < 0.025

DISCUSSION

The purpose of this study was to investigate the post-exercise cardiometabolic response of blood glucose, blood triglycerides, BP, and HR between our two experimental conditions. Our HICE condition, designed to emulate the "7-minute challenge" app, provides an alternative form of exercise completed in 7-min consisting of both resistance and aerobic body weight exercises. The main findings conclude that HICE stimulated a significant lower overall DBP compared to HIIE, specifically immediately post-exercise, following a gradual rise to pre-exercise values. There was no difference in post-exercise overall and at each time point for SBP. Overall HR was significantly higher post-exercise and at each time point, except at (45-min), in HICE compared to HIIE. There was no difference on overall response in blood glucose and blood triglycerides post-exercise. However, blood glucose was significantly higher immediately post-exercise in HICE. Based on the results, HICE appears to reduce post-exercise DBP, however elevates post-exercise HR. However, it should be noted that our HICE protocol elicited a higher HR response during activity than HIIE (145.2 ± 16.9 *vs* 126.3 ± 12.1 bpm) and could potentially be the reason for the increase in post-exercise HR response.

The cardiometabolic benefit of exercise is well known, and specifically HIIT exercises involving cycling or treadmill protocols has been demonstrated to be an effective treatment for reducing cardiometabolic risk (3, 5, 6, 12, 40, 42). However, in comparison to our study, these studies have differed on exercise lengths, modes of activity, and outcomes measured. When evaluating length of activity, previous research has evaluated HIIT activity bouts ranging from 17 min to 40 min. For these studies, they have determined beneficial responses for BP, insulin, and insulin sensitivity, cardiorespiratory fitness, norepinephrine, nitrite/nitrate, endothelin-1, and pulse wave velocity, HR recovery, VO_{2max}, oxygen consumption at respiratory compensation point, decreased plasma triglyceride, area under the plasma glucose, and ejection fraction (3, 5, 6, 12, 40, 42). Unique to our study was the use of the phone application protocol that uses 7 min to complete all activity. The brevity of this protocol would be attractive to individuals who are limited on time and but aim to sufficiently meet ACSM's resistance exercise guidelines, while also providing cardiometabolic benefit. However, the previous literature demonstrates that longer durations of activity maybe be more beneficial at reducing cardiometabolic risk. For example, our study found no overall difference between conditions (p = 0.104) however, Rynders et al. found that after approximately 24 min of HIIT significant reduced blood glucose compared to control (42). In regard to BP, Rossow et al. HIIT protocol found a reduction in SBP and DBP by approximately 5 mmHg and 6 mmHg, respectively (40). Rossow et al. reduction in BP was potentially caused by the extend duration and higher intensity of the exercise bout compared to our protocol (40).

When reviewing the HIIT literature for modes of activity, previous studies that have utilized HIIT protocols implementing resistance-training exercises are limited. Specifically to our protocol, Ludin et al. and Vrachimis et al. have both evaluated the use of bodyweight resistance exercises on cardiometabolic health outcomes (25, 46). However, both studies are of a longer study duration (6-12 wk) compared to our acute 1-d protocol. Interestingly, these studies determined that engagement in these resistance exercise programs can improve fasting glucose and DBP (25) as well as body composition, VO_{2max}, and muscular strength (46). With the addition of our study, some of these benefits (DBP) can be observed in an acute 1-d period. However, it appears more consistent use of these protocols elicits greater benefit for the health outcomes in question. Further research should be done to determine if other health outcomes not explored in this study can benefit from this acute 7-min protocol.

Though our study did not utilize a control group, our results depict no difference for SBP and triglycerides should not be overlooked. Traditional exercise has demonstrated a reduction in both SBP and triglycerides following activity when compared to controls; however, this could be linked to duration of activity and energy expenditure of that activity, respectfully (4, 8, 14, 17, 26, 41, 47). Studies finding a reduction in SBP from acute bouts of exercise typically utilize a durational bout of 30 min or more (13, 20). However, there are studies with shorter durations (2-3 min) that have found a reduction in BP (9, 23). Yet, the population in these studies were individuals with a chronic disease who have elevated BP signifying area for improvement while our participants were normotensive. As for triglycerides, our 7 min of HICE may not have sufficiently increased energy expenditure beyond the cycle activity resulting in no difference in triglycerides between the conditions (44). In order for a reduction in triglycerides to occur post-exercise, previous research demonstrates that it is dependent on energy expenditure and is typically observed in prolong endurance events (44). Additionally, with a single bout of exercise, reductions in triglycerides are not typically observed immediately and usually are observed 18-24 hr post-exercise (44). Our 1-hr post-exercise data collection may not have been on the optimal window to observe any differences in triglycerides. Since our study did not utilize controls, we cannot make the argument that we would have observed improvements compared to control for HICE, but our similar responses in HICE compared to HIIE for these outcomes should be investigated further to see if that benefit exists beyond a control group.

Our study's purpose was not to investigate specific mechanisms but, we speculate a potential mechanism on the reduction of post-exercise BP. During post-exercise recovery in our study, HR remained elevated therefore, cardiac output remains increased. However, total peripheral resistance is decreased due to vasodilation, which could have caused our post-exercise hypotension in both conditions, but more so in our HICE protocol due to higher exercise demand (7, 37). As for a glucose response, we speculate the activation of both upper body and lower body muscles groups in the HICE protocol increased glucose uptake after exercise compared to only lower body muscle activation in HIIE via exercise-mediated pathways for glut4 translocation (38).

Strengths of our study include our crossover study design, utilization of a novel time frame (7-min), controlled cadences for each exercise to standardize across participants, and collection of data at multiple time points to depict a time course. Our study design allowed for within-subject comparisons strengthen our comparisons and our period of 7 minutes added to the previous literature that typically used longer durations of exercise. By controlling the cadence of each exercise, we insured that all participants moved at the same rate, generating a similar intensity for all. Finally, by measuring at multiple time points, we were able to analyze individually; furthering the understanding of how responses to this type of exercise evolves as time extends after cessation of the activity. This will aid in determining how often these exercises should be done throughout the day and help to guide individuals seeking benefits from this type of exercise.

It is important to acknowledge limitations in this study. The two protocols did not match the same intensities during exercise when comparing the average HR. The significant difference in HR between the two sessions may play a role in our post-exercise responses. Though we made an effort to utilize a cycle protocol that would elicit similar moderate-to-vigorous intensities as the body weight exercises, the inclusion of both upper and lower body movement as opposed to lower body movement alone could be responsible for the difference. Future studies should attempt to compare these protocols with more tightly controlled and matching intensities, potentially using energy expenditure to match experimental groups. Due to this study being a pilot study, the sample size was only twelve participants producing limited results that may have inhibited our ability to detect a significant response. Though it is encouraging that with our limited sample size, we still observed modest DBP and glucose benefits. Lastly, our participants were apparently healthy and normotensive. Though this is not a limitation, we do caution readers in generalizing our results to other populations.

In conclusion, utilizing a brief bout of body weight exercises appears to reduce post-exercise DBP, could potentially increase post-exercise HR. Individuals attempting to reduce BP via behavioral changes might gain a benefit from exercise that is guided by phone apps designed to elicit beneficial responses in a short amount of time. Furthermore, this protocol will aid in individuals meeting guidelines of engaging in resistance exercises that target all major muscles groups. The brevity of this protocol allows for periods of implementation across the entire day, such as within the workday, as well as populations with various disease states who are unable to engage in longer bouts of activity. Additionally, investigating this protocol and the role it can play on the chronic management of BP should be of interest.

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