UNIVERSITY BASED HIIT CLASS ELICITS FAVORABLE FITNESS ADAPTATIONS

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the Degree

Master of Science

In

Kinesiology

by

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CERTIFICATION OF APPROVAL

I certify that I have read UNIVERSITY BASED HIIT CLASS ELICITS FAVORABLE FITNESS ADAPTATIONS by John Allan Gatbonton Penacerrada, and that in my opinion this work meets the criteria for approving a thesis submitted in partial fulfillment of the requirement for the degree Master of Science in Kinesiology at San Francisco State University.

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The purpose of this study is to examine the effects of HIIT in a University setting, in relation to implementation, volume, short and long term effects on the human physiology. The study is using retroactive data from a HIIT class administered for a full semester totaling 24 workouts. 38 males and 169 females, N=207 participants from 6 different class sections with mean age of 21.39±4.90 years and attendance of 0.88±0.10 percent. Cardiovascular fitness and muscular strength and endurance were tested pre, mid and post training. One-way repeated measures MANOVA showed significant differences between Test 1 vs. Test 3 in all four dependent variables at ($p \leq 0.05$). Overall this study showed that this University HIIT class improved cardiovascular fitness and muscular strength and endurance.

I certify that the Abstract is a correct representation of the content of this thesis.

Chair, Thesis Committee

5.21.19
Date

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The United States is the leading country for health and obesity related issues. According to the Centers of Disease Control and Prevention (CDC), more than 69.2% of U.S. adults are overweight or obese, with nearly 35.9% (over 61 million people) meeting the criteria for obesity. Associated with this issue is the increase of cardiovascular disease, diabetes, cancers, and high blood pressure, all related to having poor diet and lack of activity. An estimated $69-$115 billion a year is spent on medical due to this epidemic (CDC). This problem is not only affecting the United States, but it is spreading throughout other countries.

In recent years, exercise has shown beneficial effects in patients with cardiovascular disease, even with those who have impaired cardiac function (Wisloff et al., 2007). It is estimated that by 2020 cardiovascular disease will be responsible for 25 million deaths worldwide (Agarwal, S. K. 2011). However, reducing cardiac mortality can be achieved through exercise programs, which have shown to reduce cardiovascular disease by approximately 20-26% in comparison to standard medical care (Moholdt et al., 2009). The CDC recommends 30 minutes of moderate physical activity all days of the week, and the American College of Sports Medicine (ACSM) recommends vigorous intensity exercise at least 3 times a week for a total of 150 minutes a week. Some of the improvements in the heart that come from participating in these types of exercises include increased left ventricular end diastolic diameter, wall thickness, and function (Schmidt et al. 2014).

Often there are two types of training modalities that are compared when looking at cardiovascular fitness (Moholdt et al. 2009). One of which is Endurance training, which requires the participant to sustain exercise at a submaximal workload for an extended period of time (Gibala, et al. 2006). The other type of training is high intensity interval training (HIIT) that is characterized by exercise that involves intermittent bursts of high intensity exercise followed by a period of rest or low intensity exercise (Gibala, et al. 2012). HIIT is a form of training that provides a workout in which participants can complete a high intensity workout in a short period of time (Wisloff et al. 2007). Exercise may provide favorable cardiovascular adaptations, however there is still controversy regarding the format of the exercise format that produces the most beneficial effects (Wisloff et al., 2007).

Research involving interval training suggests that HIIT training is an efficient modality to improve cardiovascular function (Gibala, et al. 2012). One such article by Schmidt et al. (2014) described European football as a type of aerobic interval training that helped reduce cardiac dimensions often seen with aging, as it causes a volume overload within the heart to provide adaptations such as left ventricular wall thickness, left ventricle diameter, left ventricle ejection fraction, and mitral inflow velocity. Schmidt also suggests that a dose-response relationship is applicable for this modality and that it may not require extensive training. However, since HIIT has only recently been a topic of research, there are still numerous questions on the application of HIIT, especially for longer periods of time. Several questions remain unanswered: What training strategy provides the most efficient cardiovascular adaptations and performance? How does HIIT affect muscular performance, in particular strength and endurance?

Traditionally, moderate endurance training has been a favorable option, but HIIT may provide even more efficient training. In Skelly, L. et al. (2014), the authors compared the 24-hour oxygen consumption between individuals engaged in a traditional HIIT program(s) versus traditional continuous moderate-intensity training. Previous studies showed that short-term high-intensity interval training induces physiological adaptations that are similar to continuous moderate intensity endurance training (END) despite a reduced total exercise volume and time commitment. An example protocol consisting of 10 × 60-s bouts efforts at an intensity eliciting ~90% maximal heart rate (HR_{max}), interspersed with 60 s of recovery, has been shown to induce similar adaptations to Wingate-based and END protocols. Since there are limited studies on HIIT's effect on post exercise metabolism, this study compared the 24-hour energy expenditure following a bout of HIIT and END.

This study used nine trained men that performed 3 trials in random order on a cycle ergometer. The trials were HIIT, END and a control group. The HIIT trial involved 10 sets of 60 second intervals at a workload ~90% HR_{max} and then 60 seconds of active recovery. The END protocol consisted of cycling at a workload that elicited 70% of HR_{max} for 50 min. They collected VO_{2max} during exercise and 24 hours after the exercise bouts.

Results revealed that HIIT elicited a measurable increase in 24-hour energy expenditure, to an extent similar to that induced by moderate-intensity continuous exercise. The END training lasted twice as long and involved twice as much mechanical work than HIIT and yet yielded similar results. They found that although the oxygen consumption during HIIT was lower versus END, total oxygen consumption over 24 hours was similar.

In similar fashion, Little, J. et al. (2014) demonstrated how HIIT in a short- term application induced changes in participants' physiological function. In this study, the authors examined the impact of HIIT compared with continuous moderate intensity endurance training exercise on postprandial hyperglycemia in overweight or obese adults. Postprandial hyperglycemia (PPG) is an independent risk factor for cardiovascular disease and mortality in individuals with (Cavalot et al. 2006, Cavalot et al. 2011) and without type 2 diabetes (Lin et al. 2009). According to Roberts et al. (2013), and Newsome et al. (2013), exercise improves glycemic regulation, an effect that can be attributed, at least in part, to the acute increase in skeletal muscle insulin sensitivity that persists for approximately 24–48 hours following each bout.

In this study, 10 inactive, overweight or obese adults completed two 3-day experimental testing periods, separated by 7 days. The participants performed either a bout of HIIT, 10 sets of 1-minute exercise at approximately 90% peak heart rate with 1-minute recovery periods or matched work END of 30 minutes at approximately 65% peak heart rate, in a randomized, counterbalanced fashion. Real time glucose values were monitored for 24 to 48 hours pre and post exercise. Postprandial glucose (PPG) responses to lunch, dinner, and the following day's breakfast were analyzed and compared with a no-exercise control day. The coefficient of variation was calculated using the reproducibility method error technique (23) to compare values for all variables between the 2 control days. A one-way repeated measures ANOVA was performed to compare HIIT, END, and control day data for CGM variables.

Their results showed that exercise did not affect the PPG responses to lunch but performing both HIIT and END in the morning significantly reduced the PPG incremental area under the curve following dinner when compared with control. The PPG and the PPG spike following breakfast on the following day were significantly lower following HIIT compared with both END and control.

The major finding in this study was that a single session of HIIT improved postprandial glycemia in overweight or obese adults during the 24 hours following a single training session. HIIT resulted in better effects on postprandial glycemia than the more traditionally prescribed END. The HIIT response lasted into the next day despite having the 2 bouts matched for total work. These results suggest that HIIT is effective for improving glucose control in individuals who may be at elevated risk for type 2 diabetes.

In support of this study's findings, Hazell et al. (2012) reported that a single session of low-volume HIIT elevated oxygen consumption for up to 24 hours following exercise. In their study, the increase in post-exercise oxygen consumption following HIIT appeared to be elevated above continuous cardiovascular exercise from 8–24 hours into recovery. It is possible that the improvement in next day PPG control following HIIT may be related to an elevated basal metabolic rate and may influence hepatic glucose output and (or) beta-cell function (Hazell et al. 2012).

Along with improved glycemic and oxygen consumption, short term application of HIIT has also shown effects with fat oxidation. Talanian, J. L. et al. (2006) found, HIIT was applied for two weeks the capacity of fat oxidation, mitochondrial enzyme activities, VO_2 peak and metabolic functions improved. Eight healthy and active women participated in seven HIIT applications within two weeks. On a cycle ergometer the participants performed a VO_{2max} test and a 60-minute cycling trial at ~60% of VO_{2max} before and after the two-week training. The HIIT protocol consisted of ten 4-minute bouts at ~90% VO_{2max} with 2 minutes of rest intervals. As a result, VO_2 max increased by 13% and the plasma epinephrine and heart rate were lower during the last half of the 60-minute cycling trial. The body fat oxidation increased from 15.0 ± 2.4 to 20.4 ± 2.5 g, while the net glycogen use was reduced during the post training 60-minute cycling. This is typically the response from an END type of training, but the adaptations of the mitochondrial volume and the transport of fatty acids into the cells resulted within this 2-week HIIT application.

With longer applications of HIIT, one can theorize similar results of improvement in cardiovascular adaptations and performance. With Tabata et al. (1996) study, the authors compared the effects of HIIT and moderate-intensity endurance with not only the aerobic but also the anaerobic capacity of the participants. They recruited two groups of seven individuals each. One group performed a six-week workout of moderate intensity on a cycle ergometer with intensity of 70% of maximal oxygen uptake, 60 minutes a day, for 5 days a week. While the second group performed HIIT on a cycle ergometer, also 5 days a week but the interval training consisted of eight sets of 20 second exercise intensity at about 170% of VO_{2max} with a 10 second rest in between. This protocol is now called the infamous "Tabata Training."

The END group resulted with an increase in VO_{2max} from 53 ± 5 ml.kg-1.min-1 to 58 ± 3 ml.kg-1.min-1 ($p < 0.01$) (mean ± SD) but had no significant increase with the anaerobic capacity ($p > 0.10$). In comparison, the HIIT group increased their VO_{2max} by 7 ml.kg-1.min-1 and anaerobic capacity increased by 28%. They concluded that moderate intensity endurance training improves maximal aerobic power but does not change anaerobic capacity, while high intensity interval training elicits improvement in both aerobic and anaerobic capacity.

In support of the Tabata et al. (1996) study, Foster, C. et al. (2015) also examined the effects of HIIT with aerobic and anaerobic capacity. The authors compared the effect of two HIIT protocols with END for 8 weeks of training. These authors also thread the line of the most effective HIIT modules. Fifty-five untrained college aged participants were randomly assigned to one of three groups. The Tabata group performed eight intervals of 20 seconds at 170% VO_{2max} with 10 second rests. The Meyer (other HIIT) group cycled 13 sets of 30 seconds at 100% VO_{2max} with a 60 second recovery interval.

Then the last group cycled at steady state at 90% of ventilatory threshold. All performed three times a week for a total of 24 training session.

As a result, the Tabata group increased the VO_{2max} by 18% and Peak Power Output (PPO) by 24%, the Meyer group increased by 18% VO_{2max} , and 14% PPO. And finally, the steady state group increased in VO_{2max} by 19% and PPO by 17%, all results significant ($p<0.05$). There were significant changes with peak and mean but no differences between all groups.

Interestingly enough, this study also measured the enjoyment factor of the participants. Students in the Tabata group indicated the exercise to be significantly less enjoyable than the other groups, but enjoyment for all declined during the duration of the exercise study. Although HIIT are time efficient, they may not be the most enjoyable.

Another study that applied HIIT longitudinally, Roxburgh, B. et al. (2014), not only set the testing results for 12 weeks, but also touched upon potential exercise strategies in applying HIIT to an exercise protocol. In this study, the authors were interested in comparing the effectiveness of either continuous moderate intensity exercise training alone vs. combined continuous moderate intensity training with a single weekly bout of high intensity interval training on cardiorespiratory fitness. The reasoning for this study was the limited studies that investigate the effects of the combination of continuous moderate intensity training and HIIT as well as limited data on the effectiveness of HIIT on overweight and/or sedentary populations.

Roxburgh et al. (2014) was one of the rare studies that tested for long-term effects of high intensity interval training. Twenty-nine sedentary participants, male and female, with moderate risk of cardiovascular disease, participated in a 12-week exercise training program on a treadmill and cycle ergometer. Participants were randomly assigned into three groups. One group performed a combination of high intensity interval training once a week with four sessions of moderate intensity training. Another group followed a moderate intensity only, and the third was a sedentary group. The interval training consisted of 8-12 sets of 60 seconds at 100% VO_{2max} on a treadmill with 60 seconds recovery, while the moderate continuous training consisted of 15-minute treadmill and 15-minute cycle ergometer bouts at 45-60% heart rate reserve. The continuous moderate intensity group performed five sessions a week.

As a result, the combination group's VO_{2max} increased by 10.1%. The moderate intensity only group increased VO_{2max} by 3.9% while the sedentary group decreased by 5.7%. The results for both training groups were favorable, however, they found that the difference between the effects of both groups on VO_{2max} appeared to be clinically insignificant.

The main finding of this study was that the combination group and the moderate intensity group are both potential training strategies for improving cardiorespiratory fitness. Although their results did not clarify if there were significant differences between the two exercise groups, this study does provide preliminary evidence on the minimal application of high intensity interval training in regard to frequency, to elicit favorable changes in cardiorespiratory fitness. This idea is in-line with potential future studies that may focus on identifying the optimal frequency, intensity, time, and type for HIIT.

In relation to improved aerobic and anaerobic capacity, questions may arise whether HIIT improves or effect muscular performance (strength and endurance). One study by Gibala, M. et al. (2006), examined the effects of HIIT on muscular performance. The authors of this article determined short-term sprint interval training had similar adaptations as traditional endurance training, regarding adaptations in human skeletal muscle and exercise performance. At the time of their study, there were limited studies on HIIT vs. Endurance Training. It's known that endurance training induces countless physiological adaptations for improved fitness levels. But high-intensity interval training is thought to have less effect on oxidative capacity within the muscles. Therefore, they looked at muscular and molecular adaptation in skeletal muscle after high volume endurance training and low volume sprint-interval training.

Sixteen active men were randomly assigned to either a HIIT group or an Endurance Training group via cycling. The HIIT group, performed four to six sets of 30 second all out sprint with 4-minute recovery in between, while the Endurance Training performed 90-120 minutes of continuous cycling at 65% of VO_{2max}. The HIIT group trained 90% less volume than the other group. Muscle biopsies were obtained before and after training to observe oxidative capacity, muscle buffering capacity and muscle glycogen content.

The muscle biopsies exhibited an increase in COX maximal activity but with the COX II and IV mRNA's unchanged. The muscle buffering capacity increased by 7.6 % with HIIT while the Endurance Training group increased by 4.2%. And finally, the resting glycogen content increased after training by 28 and 17% for the HIIT and Endurance Training group(s) respectively.

The major findings in this study show that two different types of training can elicit the similar advances with muscular oxidative capacity. The high level of muscle fiber recruitment with HIIT is comparable to the oxidative capacity with endurance training. Both training protocols also generated increases in muscle buffering capacity and glycogen content. And although the HIIT volume application differs from the volume of Endurance training, HIIT shows that it can be a time-efficient strategy similar to endurance training.

In support of the Gibala, M. et al. (2006) study, Buckley, S. et al. (2015) sought to look at the different modes of HIIT and their effect on muscular performance. Despite the different studies supporting metabolic adaptations, HIIT studies are limited in regard to muscle strength benefits. In this study, they compared the physiological changes of traditional HIIT using a rower, and multimodal HIIT, using a circuit of modalities including strength exercises. This study is also in-line with supporting the different approach on the most efficient strategy of HIIT.

They recruited 28 active women in a 6-week study who were separated into the two HIIT training systems. They were tested on max aerobic power, anaerobic threshold, respiratory compensation, anaerobic power, and then muscle strength variables. They tested 1-RM on squats, press, dead lift, and broad jump distance as well as squat endurance test. The training duration was 6-weeks for both groups, with sessions for 60 min 3 times a week. The 60 min session was broken down into 20 min of active warm-up, 24 min training and 16 of cool down. The rowing group performed 60s of all out intensity followed by 3 min of rest for 6 rounds. The multimodal group also performed 60s of all out intensity followed by 3 min of rest for 6 rounds but with strength exercises.

The results are as follows for Multi Modal HIIT vs. Row HIIT: increase in maximal aerobic power (7% vs. 5%), anaerobic threshold (13% vs. 12%), respiratory compensation threshold (7% vs. 5%), anaerobic power (15% vs. 12%), and anaerobic capacity (18% vs. 14%). The Multi Modal HIIT group had significant ($p < 0.01$ for all) increases in squat (39%), press (27%), and deadlift (18%) strength, broad jump distance (6%), and squat endurance (280%), whereas the Row-HIIT group experienced no increase in any muscle performance variable (p values 0.33–0.90).

The major findings suggest that both HIIT groups resulted in an increase in all parameters. The results were similar for anaerobic and aerobic adaptation, but the Multi Modal group showed a greater increase in muscle performance than the Row HIIT group. This shows how HIIT is an efficient training method, not to just achieve metabolic, aerobic and anaerobic benefits, but depending on the type of HIIT training, can also produce adaptations in muscle strength, power and endurance.

Increase in mitochondrial density can also be related to not just metabolic adaptation but muscular efficiency. In Burgomaster, K. et al. (2008), the authors attempted to show how HIIT stimulates improvements in muscle oxidative capacity comparable to levels reached by endurance style training. The HIIT and END group were tested before and after 6 weeks of training. The HIIT group protocol consisted of six 30 second "all out" Wingate Test with 4.5 minutes of recovery in between intervals, 3 days a week. END was performed at 40-60 minutes of continuous cycling at ~65% of VO_{2max}, 5 days a week. Even with the difference in volume, both protocols induced similar improvements with mitochondrial enzymes for skeletal muscle carbohydrate, protein and lipid oxidation. These increases results in improved fat and carbohydrate breakdown for fuel and an improved muscle metabolic function. With the lower training volume of the HIIT group, this study's results suggest that high intensity interval training is an efficient exercise procedure to increase skeletal muscle metabolic adaptations that are similar to that of traditional endurance training protocols.

Summary of Literature

There is a consensus in regard to performing physical activity for health benefits and maintenance, but the recommended application can vary per individual which at times can be unclear. As mentioned previously, ACSM recommends 150 total minutes a week for health benefits at a moderate intensity exercise while the time doubles in regard to weight loss. Although there is overwhelming scientific evidence on the effectiveness of performing physical activity for improving health and avoiding chronic disease, the population in the United States and even other western nations fail to perform minimal exercise. According to Godin, G. et al. (1994), the most common reason of not exercising is having "no time." Unfortunately, this excuse has become the accepted reason of our failure to achieve a healthier lifestyle. Because studies have shown the efficiency of HIIT, it seems logical that the application of HIIT should become one solution for attaining a healthier lifestyle at a minimum time demand. There is a growing excitement and appreciation of the benefits of HIIT to stimulate health and fitness improvements.

Purpose of the Present Study

Over the past several years, a San Francisco State University (SFSU) Aerobic class has evolved into a HIIT based exercise program. With favorable studies of HIIT and the growing popularity at local fitness centers, the class gives students exposure to the latest fitness programs that are offered in the health and fitness industry. In reference to the statistical findings of how much college students are also susceptible to a decline in health and fitness, in a study by Racette, S. B. et al. (2005), 70% of students during the first 2 years of college can potentially gain ~9 lbs. of weight due to lack of regular exercise and unhealthy eating patterns. Along the lines of time being a challenge, this class at SFSU is only available twice a week with a total exercise time of about 60-80 minutes a week. With the limited time this class is offered during the week but is at a length of a full semester or 12-14 weeks, the following question will be addressed in this study: Is a University based HIIT class (meets twice a week for 40 min, 14 weeks, 24 workouts), enough to elicit favorable training adaptations (cardiovascular and muscular strength and endurance)?

Method

The University based HIIT class at SF State University is offered during a regular 16-week semester to all college grade levels. Within the course, four dependent variables were collected as a means to reveal whether the participating students experienced any fitness adaptations through the length of the semester: Resting Heart Rate (RHR), YMCA 3-Minute Step Test (Step Test), YMCA 1-Minute Half Sit Up, and ACSM Push Up. There were no prior intentions of using the data for any study attenuating any bias for favorable results. Students that did not complete the course were excluded from the data analyses.

Participants

Although a regular semester is 16 weeks, the class met twice a week, with the actual fitness activities conducted within 12-14 weeks due to breaks, holidays, pre-fitness training preparation, and fitness testing, totaling 24 workout classes. Data were used from six different class sections. Section 1 had 21 students, Section 2 had 16, Section 3 had 40, Section 4 had 48, Section 5 had 50 and Section 6 had 32 students, with each section taken place within the years 2008 to 2018. There were 38 males and 169 females totaling N=207 participants, with ages 18-71 years old with a mean of 21±4.90 and attendance at 0.88±0.10. See Table 1 for participant description.

Gender - Male - Female	 38 169
Class Sections Participants - 1 - 2 - 3 - 4 - 5 - 6	 21 16 40 48 50 32
Age in Years (Mean / STD)	21.39±4.90
Attendance Percentage (Mean / STD)	0.88±0.10

Table 1: Participant Description. The class sections show how many participants per section. The Age and Attendance are shown as mean ± standard deviation.

Procedure

The class structure was as follows. The first week, the class participants were introduced through a thorough process of rehearsing the fitness tests to build comfort in gathering results. The specifics on the fitness tests are detailed later in this section. The first fitness tests were performed at the beginning of the following week and the results were gathered as Pre-Test (Test 1). Directly after, 6 weeks of workouts were held with the participants exercising two times a week, for 40 minutes per bout with one rest day in between workouts for the week. The HIIT workouts were total body exercises consisting of calisthenic type of exercises; jumping jacks, cross jacks, mountain climbers and burpees, and body weight strength exercises; push-ups, squats, lunges and planks.

The first 5-10 min was a warm up with dynamic movement exercises to assist in conditioning the body for more rigorous training. Then 30 minutes of HIIT was administered by performing through calisthenics and bodyweight strength exercises in a manner in which the participants were cycling through moderate and vigorous levels of intensities. They exercised at a high intensity level for 20 seconds and then transitioned to a high to moderate intensity for another 20 seconds and then finally to a moderate intensity for another 20 seconds. This was repeated for 2-3 sets and followed by 1-minute rest period. As defined by American College of Sports Medicine (ACSM), moderate intensity is between 64-77% of the Heart Rate Max (HR_{max}) while vigorous intensity is above or equal 77% of HR_{max}. During the first week of rehearsal, the participants were instructed how to determine each individual's heart rate levels by using the HR_{max} calculation; ($220 - age = HR_{max}$) multiplied the by percentage values given and understanding which exercises and their intensities were needed to achieve these heart rates during the workout. During the workout, intensity levels were monitored by checking their heart rate during specific times of the workout to ensure the participants were at the correct intensity level, a usual practice in aerobic fitness classes. A 5-10-minute cool down was then performed with low intensity exercises and stretches. Please see Appendix A for more details of the first exercise program.

Mid-testing was then administered after the initial 6-week workout as a midterm exam (Test 2). Directly after, a new format of HIIT was administered for variety and in attempt at avoid plateau in the participants' fitness. For this 6-weeks, HIIT was formatted in a circuit class with having 8-10 exercise stations. The participants would spend 30-45 seconds on an exercise station, with 15 seconds of active rest, transitioning to the next exercise station. This pattern was continued until the participant finished all the stations equaling to one set. A minute rest period was given after each set and then another set began with time permitting. This continued for 30 minutes followed by a 5-10-minute cool down section with low impact exercises and stretches to end the workout program. See Appendix B for more details of the second exercise program. Final fitness testing was then administered and gathered at week 16.

Measures

The Fitness Tests were led by the class instructor with each participant in the class involved in gathering results. The participants would work with a partner and gather each other's resting heart rate, cardiovascular fitness test results and muscular strength and endurance test results. These protocols are universal standards used for gathering physical fitness performance (Zhang, D., et al. (2015), Bohannon, R. W. et al. (2015), Diener, D. H. et al. (1995), Baumgartner, T. A. et al. (2002)). Although there are other protocols considered more clinical, for the purpose of practicality and resources available these were chosen for the class.

Testing for cardiovascular health and endurance is an important component of physical fitness. Resting heart rate is an accepted predictor for cardiovascular mortality within the general population (Zhang et al. 2015). Each participant would record their resting heart by manually counting the pulse on their carotid artery or ulnar artery for a minute. Capturing VO_{2max} is the gold standard for measuring cardiovascular endurance but requires instrumentation that is not as practical for the HIIT class. As an alternative a submaximal functional test, the YMCA 3-Minute Step Test was used as an accepted option. The validity, reliability and responsiveness of this option has been well established (Bohannon et al. 2015).

For the muscular strength and endurance, two types of tests were used. The first one was the YMCA 1-Minute Half Sit-Up Test. It has been found to be reliable and is an accepted method in testing for abdominal strength and endurance (Diener, M. et al. 1995). The other test used was the ACSM Push-Up Test. Again, this test has been well documented as a reliable means of measuring upper body muscular strength and endurance (Baumgartner, T. et al. 2002). Appendix A shows the protocols in detail for conducting the fitness tests listed.

Results

SPSS software was used for statistical analyses. One Way Repeated Measures MANOVA was examined as suggested by Tabachnick and Fidell (2007). Values for skewness and kurtosis for variables were assessed; age and attendance were skewed and not used as covariates. Gender and class section were used as covariates, but no significant differences emerged. Wilks' overall MANOVA was significant, Wilks' $\Lambda = .601$, $F(8, 774) = 28.04$, $p<.0001$, partial $\eta^2=.23$. To compare main effects and confidence interval adjustments, Bonferroni analysis was used. Follow-up analysis revealed that significant differences were indicated for all variables. Alpha was set at $p\leq0.05$ (Cronbach, 1951).

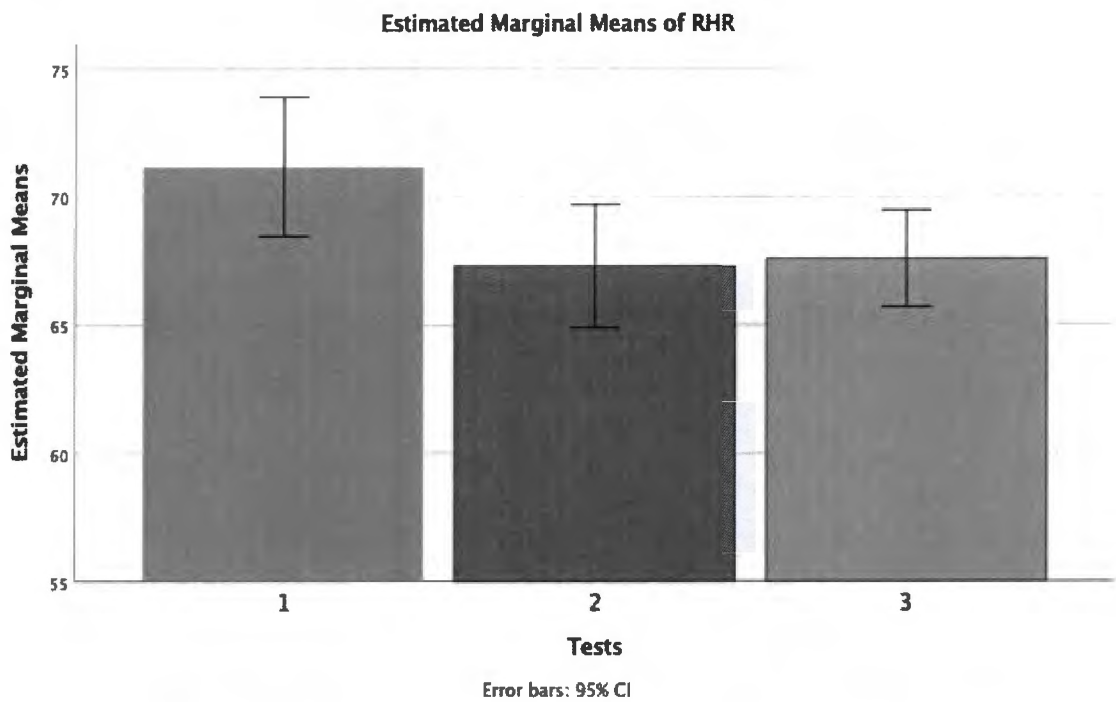
Measure	Test	Mean	Std Error	Test Comparison	Mean Difference	Std Error	Sig
Resting	1	71.189	1.381	1 vs. 2	3.896	1.185	0.004
	2	67.293	1.219	2 vs. 3	-0.281	0.971	1.000
	3	67.572	0.954	1 vs. 3	3.615	1.232	0.011
Step Ups (b/min)	1	99.469	2.640	1 vs. 2	2.171	2.043	0.868
	2	97.298	1.866	2 vs. 3	4.699	1.624	0.013
	3	92.599	1.780	1 vs. 3	6.869	2.214	0.007
Sit Up (# of reps)	1	36.137	1.182	1 vs. 2	-7.270	1.111	0.000
	2	43.407	1.107	2 vs. 3	-2.735	0.881	0.007
	3	46.142	1.138	1 vs. 3	-10.005	1.151	0.000
Push Up (# of reps)	1	23.182	0.946	1 vs. 2	-5.307	0.714	0.000
	2	28.488	0.932	2 vs. 3	-4.671	0.772	0.000
	3	33.159	0.940	1 vs. 3	-9.978	0.843	0.000

Table 2: Mean Results and Statistical Significance. Test comparison between three different test times. Alpha set at $p\leq0.05$.

Resting Heart Rate

The mean RHR for Test 1 = 71.189±1.381 b/min, Test 2 = 67.293±1.219 b/min, and Test 3 = 67.572±0.954 b/min. Paired comparisons showed significant changes between Test 1 vs. Test 2 ($p<0.004$). There were no significant changes between Test 2 vs. Test 3 ($p=1.00$). Test 1 vs. Test 3 also showed significant changes ($p<0.011$).

Figure 1: Resting Heart Rate Test

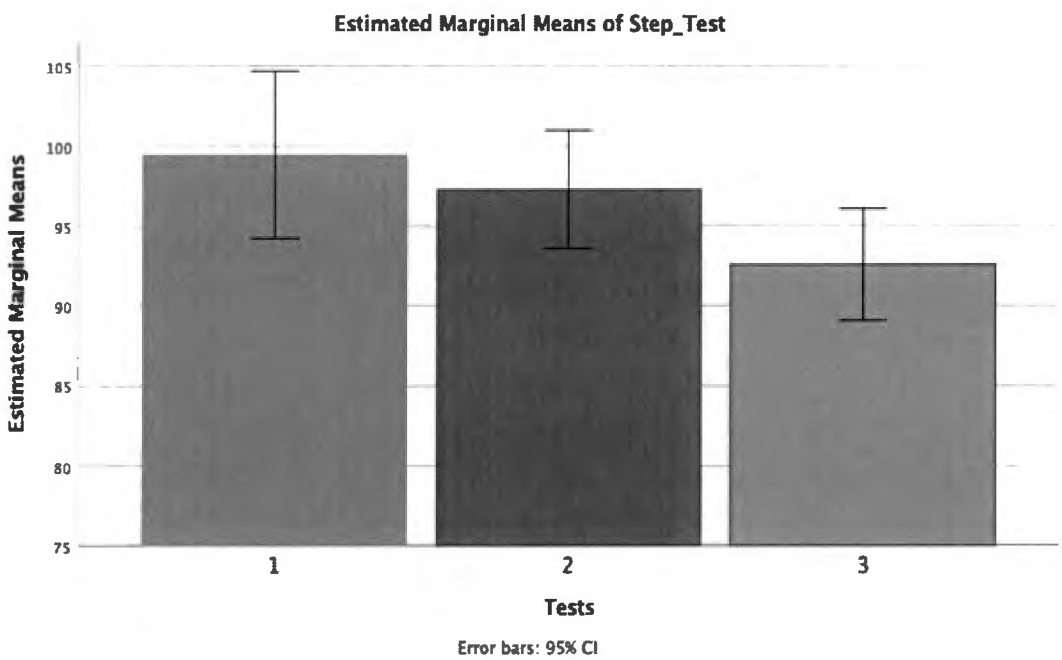


Measure	Test	Mean	Std Error
Resting Heart Rate (by minute)	1	71.189	1.381
	2	67.293	1.219
	3	67.572	0.954

YMCA 3-Minute Step Test

The mean recovery heart rate for Step Test for Test 1 = 99.469±2.640 b/min, Test 2 = 97.298±1.866 b/min, and the Test 3 = 92.599±1.780 b/min. Paired comparisons showed no significant difference between Test 1 and. Test 2 (p<0.87). Test 2 vs. Test 3 did have significant differences (p<0.01), and significant effects resulted between Test 1 vs. Test3 (p<0.007) as well.

Figure 2: YMCA 3-Minute Step Test

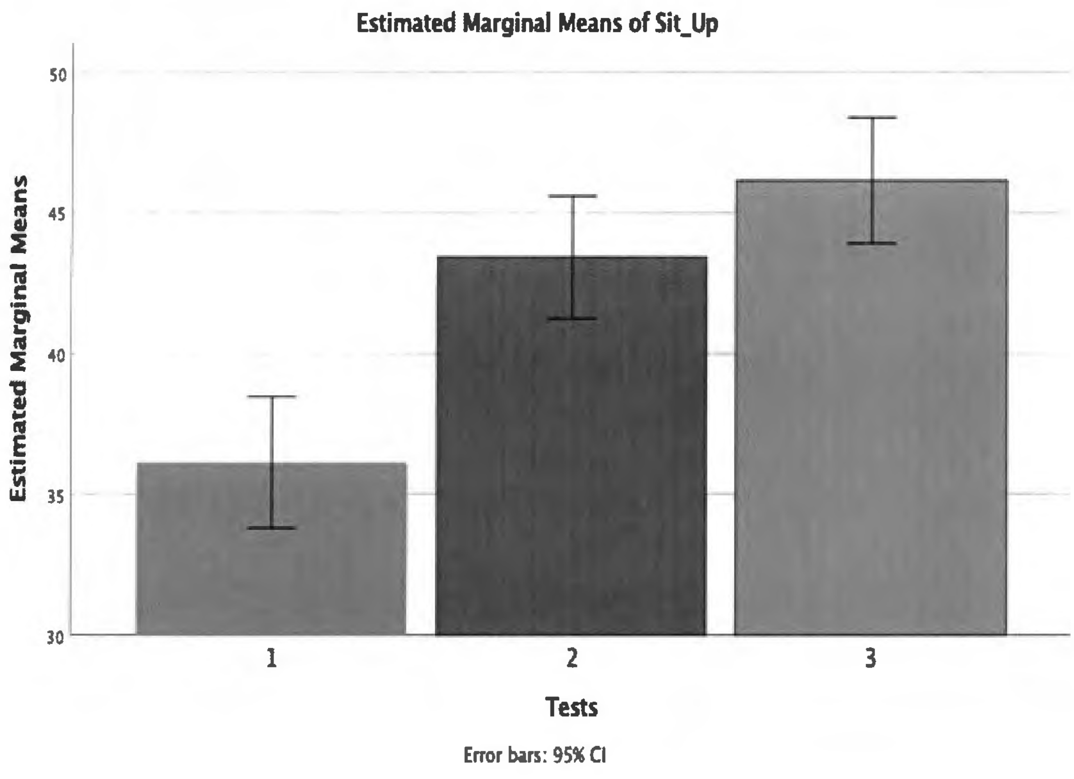


Measure	Test	Mean	Std Error
3-Minute Step Test	1	99.469	2.640
Recovery Heart Rate	2	97.298	1.866
(by minute)	3	92.599	1.780

YMCA 1-Minute Half-Sit-Ups Test

For muscular strength and endurance with the Sit-Up Test, the mean repetition for Test 1 = 36.137±1.182 reps., Test 2 = 43.407±1.107 reps, and Test 3 = 46.142±1.138 reps. The test comparisons showed significant changes between Tests 1 vs. Test 2 (p<0.0001), Test 2 vs. Test 3 (p<0.007) and Test 1 vs. Test 3 (p<0.0001).

Figure 3: YMCA 1-Minute Half Sit Up Test

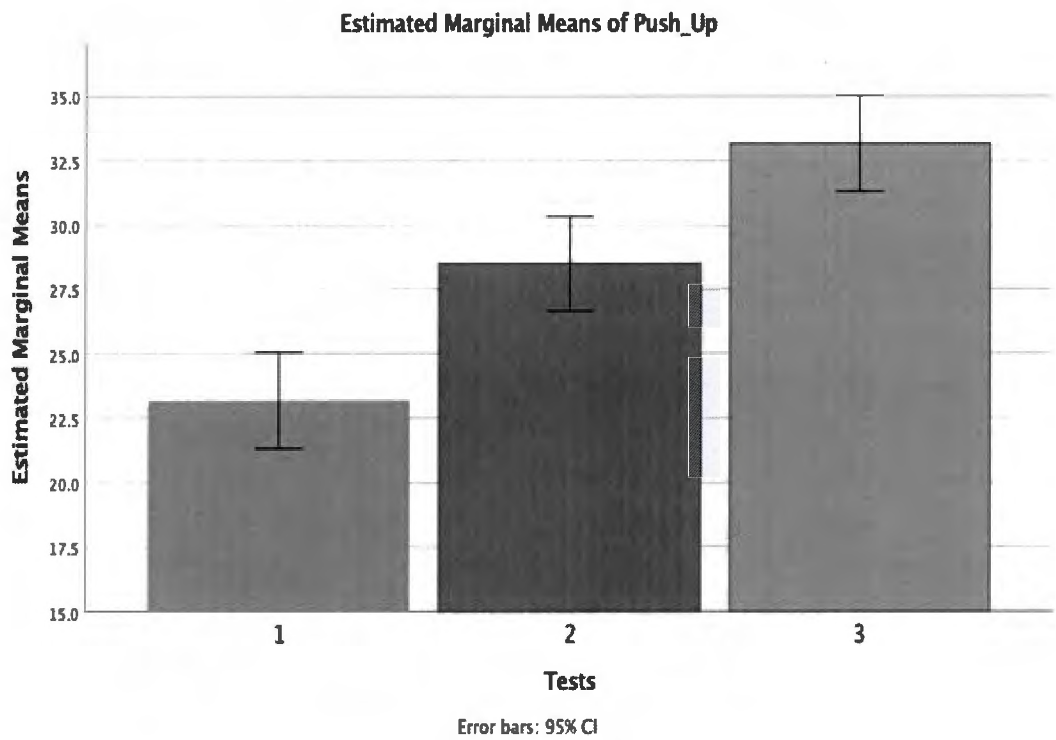


Measure	Test	Mean	Std Error
Sit Ups (by reps)	1	36.137	1.182
	2	43.407	1.107
	3	46.142	1.138

ACSM Push-Up Test

With the Push-Up Test, the mean repetition for Test 1 = 23.182±0.946 reps., Test 2 = 28.488±0.932 reps., and Test 3 = 33.159±0.940 reps. Significant effects resulted between the test comparisons with Test 1 vs. Test 2 ($p<0.0001$), Test 2 vs. Test 3 ($p<0.0001$) and Test 1 vs. Test 3 ($p<0.0001$).

Figure 4: ACSM Push Up Test



Measure	Test	Mean	Std Error
Push Ups (by reps)	1	23.182	0.946
	2	28.488	0.932
	3	33.159	0.940

Discussion

The primary purpose of this study was to determine if a University-based HIIT class can elicit positive responses in the participants' cardiovascular fitness as well as muscular strength and endurance. The overall results showed improvements with all four dependent variables (RHR, Step Test, Sit Up and Push Up) and are in line with previous studies of HIIT. With the participants' cardiovascular results, the mean RHR and recovery heart rate from the Step Test improved throughout the full training regimen with significant changes. This can be attributed to several cardiovascular adaptations, such as stroke volume increasing and increased cardiac muscle mass as a result of HIIT training (Zuhl M. et al. 2012). Improved V02max, lactate threshold and improved running economy can also be related to this improvement (Helgerud, J. et al. 2007). The results did reveal no significant changes with RHR between Test 2 vs. Test 3 which can be due to physiological adaptive training response threshold after 6 weeks of training. As the cardiovascular system improves, RHR will decrease but will eventually reach a threshold of efficiency at rest. In addition, the Step Test result having no significant difference between Test 1 vs Test 2 in comparison, can be accredited to physiological acute response after 6-weeks of training vs. adaptive training response. Although the Step Test was trending improvement, it seems that the adaptive response occurred through the full 12-week training.

As for the improvement of the muscular strength and endurance, the Sit Up and Push Up tests showed significant differences between all three test times. Again, these results are reflecting previous literature, with one in particular by Estes, R. R. et al. (2017), showed how 12-weeks of HIIT increased the cross-sectional area of the vastus lateralis and increased VO_{2max} . Furthermore, HIIT has also shown to improve mitochondrial density to deliver more energy and generate more power for a longer period of time (Gibala, M. J. et al., 2012). These are the possible mechanisms that bridges the adaptations and significant differences with the improved muscular strength and endurance for the push-up and sit-up results.

Limitations and Future Research

While the results are enlightening, limitations of the study need to be discussed. The students' experience with the fitness tests can possibly affect the results. As they undergo the fitness testing more often, their effectiveness in performing can also improve due to comfort and may not necessarily from physiological adaptation. Although it is safe to say that consistency with these workouts will elicit physiological adaptations. In addition, the use and availability of technology in a practical setting can help enhance the results. The use of heart rate monitors during the workouts can give more accurate readings of heart response during the variety of intensities. This can eliminate potential error with participants training at the proper heart rate intensity. Access to other technology for capturing biometrics such as Body Fat Composition, Weight, and Metabolic Rates would add valuable variables to this study. The effects of this University HIIT class on these biometrics can be determined with the use of equipment such as SECA or In Body Scanners. Furthermore, not having control of the participants' external lifestyle as students can pose a limitation. Nutrition, calorie intake, rest, and additional physical activities can be influenced but can be a challenge to control in a University class setting. A study of the effects of a University based HIIT class with lifestyle considerations and biometrics as variables would be a promising study invigorating potential application of HIIT and coming closer to knowing adverse effects to real life settings.

In conclusion, SF State University's HIIT class and its application of volume, frequency, intensity, time and variety of exercises, has shown improvements in cardiovascular fitness and muscular strength and endurance and can be an effective training option with addressing time challenges and efficiency.

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Appendix A

Exercise Program #1. Moderate intensity: Heart Rate = 64%-77% of HR_{max}, High Intensity ≤ 77% of HR_{max}

Warm-Up (5-10 minutes)	Dynamic Exercises	Intensity
	- Arm / Shoulder Circles - Elbow Curls - Trunk Flexion/Extension/Rotation - Hip Mobility Rotations - Ankle Mobility - Core Activation	- Low / Moderate
HIIT (30 minutes) 3-4 Sets - 20 seconds - 20 seconds - 20 seconds 1 minute rest - 20 seconds - 20 seconds - 20 seconds 1 minute rest - 20 seconds - 20 seconds - 20 seconds 1 minute rest	Cardiovascular / Strength - Jumping Jacks - Body Weight Squats - Plank to Side Plank - Cross Jacks - Lunges - Push-Ups - Ice Skaters - Side Lunges - Plank w/ Hip Flexion	Heart Rate Intensity - High - Moderate - Moderate - High - Moderate - Moderate - High - Moderate - Moderate
Cool Down / Stretch (5-10 min)	Static Stretches - Cobra Stretch - Child Pose - Downward Facing Dog - Pigeon Pose - Ankle Rotation - Chest Abduction - Shoulder Extension - Tricep Over Head Stretch	Intensity - Low

Appendix B

Exercise Program #2. Moderate intensity: Heart Rate = 64%-77% of HR_{max}. High Intensity ≤ 77% of HR_{max}

Warm-Up (5-10 minutes)	Dynamic Exercises - Light Jog - Arm / Shoulder Circles - Elbow Curls - Trunk Flexion/Extension/Rotation - Hip Mobility Rotations - Ankle Mobility - Core Activation	Intensity - Low / Moderate
HIIT (30 minutes) 3-4 sets 30 seconds / Station 15 rest / Transition 1 minute rest after all stations have been completed per set	Circuit Training Station 1 – Lunges / Sprints Station 2 – Ab Exercises Station 3 – Crawls / Burpies Station 4 – Bench Dips Station 5 – Step Up Variations Station 6 – Plank Variation Station 7 – Calisthenics Station 8 – Push-Ups	HR Intensity - High - Moderate - High - Moderate - High - Moderate - High - Moderate
Cool-Down / Stretch (5-10 minutes)	Static Stretches - Cobra Stretch - Child Pose - Downward Facing Dog - Pigeon Pose - Ankle Rotation - Chest Abduction - Shoulder Extension - Tricep Stretch	Intensity - Low

Appendix C

Fitness Test Protocols. Resting Heart Rate, YMCA 3-Minute Step Test, YMCA 1-Minute Half Sit Up Test and ACSM Push Up Test.

<u>Resting Heart Rate</u> Purpose: provides an estimation of cardio-respiratory efficiency Procedure: Find and count pulse (carotid or ulnar artery) for 60 seconds.
<u>3-Minute Step Test:</u> Purpose: provides a measure of cardio-respiratory or endurance fitness Equipment: 12 inch step, stopwatch, metronome or cadence tape, heart rate monitor (optional) Procedure: The subject should warm-up. Subject steps up and down at a rate of 24 steps per **minute** (metronome setting of 96) for 3 minutes. Immediately after the **three** minutes of stepping, the subject sits down on the bench and finds pulse (at neck). The 60 second heart rate is taken five seconds after completion of stepping. This recovery heart rate is the score. Consult the standards to determine fitness category.
<u>Sit-Up Test</u> Purpose: assess the endurance of the athlete's abdominal muscles. Equipment: flat surface, mat, watch, a partner Procedure: 1. Lie on the mat with the knees bent, feet flat on the floor, the hands resting on the thighs and the back of the head on the partner's hands 2. Curl up slowly using the abdominal muscles and slide the hands up the thighs until the finger tips touch the knee caps 3. Return slowly to the starting position 4. The feet are not to be held 5. A complete curl-up is to take 3 seconds - that is 20 repetitions/minute 6. Repeat as many curls as possible at this rate 7. Record the total number of curls

Push Up Test:
Purpose: Assess endurance of the upper body musculature.

Procedure: Client lies prone on the floor with their legs together and the hands pointing forward under the shoulders. Clients push up from the mat by fully extending the elbows and by using either the toes (for males) or the knees (for females) as the pivot point. The upper body should be kept in a straight line and the head should be kept up. The client returns to the down position, touching the chin to the mat. Clients perform as many consecutive repetitions, with no rest between reps, as possible. Terminate the test when the client strains forcibly or is unable to maintain proper push-up technique over two consecutive repetitions.