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Original Article

Effect of high intensity functional training and traditional resistance training on aerobic, anaerobic, and musculoskeletal fitness improvement

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Abstract
Problem statement: High intensity functional training is a popular training modality where individuals complete as many repetitions as possible in sequence to solicit maximal fatigue in a workout. Despite the popularity of these programs it is unclear whether this approach improves fitness more than a traditional resistance training program.**Purpose:**Thus, we aimed to understand whether muscular, aerobic and anaerobic fitnesswere improved via high intensity functional training compared totraditional resistance training.**Approach:**Thirtyhealthy male and femaleparticipants (23.2±3.2 years) were randomly assigned to free exercise, high intensity functional training, or traditional;n=10.High intensity functional training andtraditional workouts were supervised and training volume was similar while the free exercise group maintained normal exercise across the 6 weeks.The same test batterywas performedpre-post and additional physical activity recorded for each group. **Results:**Significant post training group differences were: high intensity functional training lower bodyanaerobic power was less than free exercise and traditional type training; and upper body muscle endurance was greater in high intensity functional training compared to traditional type training**.**There were significant improvements in all muscle strength measures for both types of training groups and aerobic power improved in the high intensity functional training group ($p<0.05$).However, the free exercise group also improved in many post assessments which implies a learning effect. Further, the lack of improved anaerobic fitness in either training group indicates excessive accumulated fatigue. **Conclusions:**Given our results, high intensity functional training or traditional will improve muscle strength and high intensity functional training likely improves aerobic power and upper body muscle endurance more. However, both typesof trainingare very intense and may lead to undue fatigue in recreationally active adults.
Keywords:circuit training, VO_{2max}, 1 repetition maximum, muscular endurance, muscle power

Introduction

High intensity exercise programs have been popularized in the fitness industry with participants citing unique benefits to multiple health related components of fitness(Bergeron et al., 2011). These include: changes in muscular endurance, body composition, and aerobic fitness, as well as greater ability to complete functional tasks for occupational performance(Bergeron et al., 2011). Proponents of this training approach advocate that the high intensity solicits gains in fitness that cannot be accomplished with lower intensity continuous exercise(Gibala & McGee, 2008; Hood et al., 2011). Two of the most common intermittent types of high intensity training are “High Intensity Interval Training” (HIIT)(Gillen & Gibala, 2014; O’Hara et al., 2012)and “High Intensity Functional Training” (HIFT)(Falk Neto & Kennedy, 2019).

HIFTfocuses on resistance training exercises such as a squatand overhead presses where participants are asked to complete the exercise as fast as possible, similar to moretraditional modes of muscle power training(Kraemer et al., 2002). However, HIFT has less rest between sets, asking participants to complete as many possible repetitionsin a predetermined amount of timeusing a combination of whole body exercises(Feito et al., 2018). This high repetition approach is purported to maximize metabolic stress and increase fatigue, to solicit greater improvements in multiple components of fitness compared to a traditional resistance type program(Falk Neto & Kennedy, 2019). In addition commercially available variantsof HIFT promote a new daily workout as the better path to metabolic, muscular and aerobic fitness gains. This approach of a new workout per day relies on the training principle of variety where new and varied stimulus can improve training effect and reduce monotony (Bompa & Haff, 2009). Yet, little controlled research has compared this highly varied approach to training to other forms of muscular fitness training. Interestingly, due to the variability of the workouts from day to day HIFT style variable programming has limited progressive overload in reps, sets, and volume compared to a traditional muscular fitness training program. This is contrary to the body of knowledge which associates systematic variation in progressive overload with health related gains in muscular fitness(Baechle & Earle, 2008; Ratamess et al., 2009). Specifically, traditional resistance training workouts

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organize training variables (e.g. reps/sets/rest time) in a fashion consistent with linear periodization (LP) models (Prestes et al., 2009). LP models typically organize such variables to allow for a gradual increase of training intensity while simultaneously reducing training volume over the course of a training intervention(Rhea et al., 2003), and have been shown to elicit significant strength adaptations in an efficient manner (Chilibeck et al., 1998; Fischetti et al., 2019; Kraemer et al., 2004). However, any current literature comparing highly variable inter-day type workouts to a traditional progressive overload program is limited to a few retrospective studies which were not well controlled experiments. Of the studies completed to date, retrospective studies of individuals participating in these types of variable HIFT programs compared to a general health related fitness program (Jeffery, 2012)or a traditional resistance training program(de Sousa et al., 2016)have shown varying results. Specifically, HIFT participants were found to have better anaerobic alactic and aerobic fitness (de Sousa et al., 2016; Jeffery, 2012), but upper body relative strength (as measured by pull ups) was better in resistance trained compared to HIFT trained participants (de Sousa et al., 2016). Additionally, Barfield et al.(Barfield et al., 2012)compared the post-training fitness of college-aged participants who completed a HIFT vs. atraditional resistance training class, and foundsignificantly greater upper body muscle power and bench press muscular endurance in the traditional program compared to HIFT(Barfield et al., 2012).Cumulatively, this previous research discerns that HIFT has a greater influence on energy systems fitness likely due to less rest throughout the workout and greater number of repetitions performed. Conversely, traditional progressive overload resistance training seems toimprove muscular strength and endurance to a greater degree than HIFT style workouts which reflects the fitness outcomes associated with resistance training guidelines(Pollock et al., 1998).Thus, both HIFT and traditional resistance training improve fitness however there is a lack of research which prospectively compares these different methodological training approaches to improvethe health related aspects of fitness.

Therefore, the purpose of the current study was to understand whether a highly variable HIFT approach to training results in greater gains in anaerobic and aerobic power, muscular endurance, muscle strength and power fitness compared to a periodizedtraditional resistance training program. Based on previous findings, it was hypothesized thatHIFT would solicit significantly greater increases in bothanaerobic and aerobic power compared to traditional resistance training. Traditional resistance training,on the other hand, was hypothesized to solicit greater gains in upper and lower body muscular endurance, muscle strength, and muscle power.

Materials and methods

Participants

Thirty female and male participants were recruited from the local University and urban community. Recruitment was performed via posters placed around campus and in other high traffic fitness centers in the urban area surrounding the University.Individuals expressing interest contacted the primary investigator (via email) to schedule aninitial fitness assessment and were provided a detailed information letter and informed consent. Inclusion criteria includedbeing between 18 and 30 years of age with habitual physical activity (≥2x per week for ≥ 6 months). Participants were novice resistance trained individuals with no current or previous history of regular muscle strength or muscle endurance training. We felt recruiting novice was an important aspect of this study because baseline measurements would be similar between groups. Participants who had a current injury, had sustained an injury recently (that would have compromised their ability to perform prescribed exercise)were excluded. This study received Institutional Research Ethics Board approval, and all participants provided informed consent(Pro00072960) in compliance with theDeclaration of Helsinki - Ethical Principles for Medical Research Involving Human

Subjects.We determined that 8.5 participants per group was sufficient to see changes in our study based on previous pre-post changes of relative muscle power due to high intensity training(Laffaye et al., 2014); using an alpha=0.05 and β=0.2, f=7.9for our sample size estimate. Thus, given these estimations and other previous research sample sizes we aimed to recruit 10 participants per group.

Procedure

Upon successful recruitment, participants were randomly assigned to one of threegroups:Free Exercise (FE), PeriodizedTraditional Resistance Training (TRAD), Inter-day Varied High Intensity Functional Training (HIFT). Participants in the TRAD and HIFT groups then performed 6 weeks (at a maximum frequency of 4 training sessions per week) of supervised training. Duration was chosen based on previous research indicating that significant improvements in strength, power, and endurance can be detected in training interventions lasting 6 weeks or less across a wide variety of populations(Brown et al., 2017; Gacesa et al., 2013; Manca et al., 2017), regardless of the periodization structure utilized to organize exercise variables(Pelzer et al., 2017).

Participants assigned to the FE group were asked tomaintain their pre-study exercise habits during the 6-week study period. Individuals assigned to the TRAD and HIFT groups were asked to refrain from participating in structured resistance trainingworkouts outside of project prescribed sessions and to record additional physical activity performed during the 6-week study period (i.e. non-supervised workouts and exercise bouts that included aerobic, flexibility, and/or team sport components). The FE group was asked to record all physical activity that was recognized as a “workout”(defined as a pre-planned bout of physical exertion above resting levels, consistent with ACSM recommendations for developing and maintaining cardiorespiratory and muscular fitness) (Garber et al., 2011).Participants in this group were provided examples of the minimum thresholds for cardiorespiratory and muscular fitness to guide what was recorded as a “workout”.

Physical activity data for all groups was self-logged in individual digital exercise diariesfor the entirety of the 6 week study period. Thisprovided the ability to not only quantify the total amount of stress for the prescribed intervention workouts (TRAD and HIFT), but also the global amount of activity done by each participant in each group. All recorded activity qualifying as a “workout” was then categorized as light, moderate, or vigorous to provide inferences between group differences in training intensities which may have influenced results.Intensity categories were based on subjective session-based rating of perceived exertion (RPE) (based on the Borg CR-10 scale) following each training session(Borg, 1990). This scale ranges from 0-10, where 0 indicates an exercise intensity equivalent to rest (i.e. no effort), and 10 indicates an intensity equivalent to maximal effort. Then, each reported exercise session was given an intensity rating (i.e. light, moderate, or vigorous intensity exercise) based on standards provided by the Canadian Society for Exercise Physiology (light effort = RPE of 0-3; moderate effort = 4-6; vigorous effort = 7-10)(Canadian Society for Exercise Physiology, 2013). Summation of the total number of exercise minutes accumulated for each intensity category was subsequently determined for each group. The FE participants were asked to maintain their pre-study training and exercise habits for the 6 week study period. HIFT training was derived from program descriptions previously used to train individuals in academic studies(Drake et al., 2017; Paine et al., 2010) using a commercially available recommendations to develop the overall program (Glassman, 2010).Each workout followed a warm-up, strength/skill, and main HIFT bout (in that order)where the number of sets and reps for each exercise in the main bout differed for every workout. Exercisesincluded: deadlift, handstand pushups, pull-ups, thrusters, pushups, squats, kettlebell swings, box jumps, wall balls, burpees, hang cleans, front squats, back squats, standing shoulder press, tricepbrachii dips, and overhead squats. Speed of movement was emphasized as important for the execution of each exercise with no rest between exercises or between circuits. Thus,the goal of each workout was to complete all prescribed sets and repetitions as fast as possible where the main bout of exercise lasted 12-20 minutes. The TRAD group 6-week training program was based on previous research utilizing periodization models in traditional resistance training(Ebben et al., 2004; Prestes et al., 2009)as well as National Strength and Conditioning Association (NSCA) guidelines for athlete development(Baechle & Earle, 2008). Each exercise prescribed included a warm-up set followed by additional sets. The goal for each exercise was for participants to choose loads that elicited a 9-10 rating (on the Borg CR-10 scale) during the last repetition of each set. A certified personal trainer demonstrated and monitored correct exercise form for TRAD participants and TRAD participants worked out in pairs.Training variables (e.g. reps/sets/rest time) in the TRAD program were organized in a fashion consistent with linear periodization (LP) models, whereby the first week of training involved performing all sets to failure at 12-14 repetitions, with target repetitions decreasing each week (to a minimum of 4-6 repetitions per set) in a time-dependent fashion. Workouts alternated between upper body musculature, and lower body musculature. These workouts were comprised of both isolation and compound exercises, including: flat bench press, incline chest fly, seated shoulder press, standing lateral shoulder raise, cable tricepsbrachii extensions, seated bicepbrachii curls, leg press, squat, deadlift, prone hamstring curl, seated quadricep extension, seated calf press, and seated latissimus dorsi pull down; exercises were performed using a combination of free weights, cables, and machines.

Measures

Each participant was screened for heart rate, blood pressure, and other health risks using the Physical Activity Readiness Questionnaire (PAR-Q). During this initial screen, participant anthropometrics including body weight, height and standing reach was also measured.Participants assigned to all groups (FE, TRAD, and HIFT) underwent the same assessments distributed over 3 days (with a maximum of 48 hours between testing sessions) pre-post study. Assessments were structured to minimize the effect of participant fatigue (resulting from the maximal effort requirements of each test) interfering with participant effort duringsubsequent measures.

Aerobic power was determined via the 20m shuttle run test administered indoors in the same location via the Leger protocol(Leger et al., 1988). Upper and lower body anaerobic alactic and lactic powerfitnesswas evaluated via standard Wingate protocols for both the upper and lower body using arm crank ergometer and bicycle ergometer (respectfully). A bicycle ergometer (Monark894E, Sweden) and arm ergometer (Monark891EW) were adjusted according to participant preferences(Jaafar et al., 2014)for lower body Wingate and for the upper body Wingate(Forbes et al., 2014). Workload resistance ratios were 0.092 kg/kg, 0.075 kg/kg bodyweight (lower body male and female), and 0.075 kg/kg, 0.065 kg/kg bodyweight (upper body male and female) based on previous research(Forbes et al., 2014; Jaafar et al., 2014). Power output every 5 seconds, peak 5 second output (relative to participant body weight), and average power output over 30 seconds (relative to participant body weight), were determined for both upper and lower body Wingates. Standardized multiple-repetition maximum (MRM) protocols for athletic populations(Darrall-Jones et al., 2015)were utilized and 1-RM values were determined according to load conversion charts previously established by the NSCA(Baechle & Earle, 2008). The following exercises were evaluated via MRM: Barbell bench press where technical failure was defined as an inability to maintain an unassisted, full range of motion over the course of a single repetition – full range of motion.; barbell back squat where proper technique was legs bent at 90 degrees or lower in the bottom position of the movement, and legs and hips fully extended in the top position of the movement; lower body isolated knee flexion and knee extension strength evaluation was performed on a weight stack machinewith positioning dictated via manufacturer instructions located on placards of both machines; upper body pull strength determined via pronated pull-up 1-RM or assisted pull-up 1-RM protocols to determine upper body, arm, and shoulder girdle fitness(Baumgartner, 2007). Upper body isometric muscular endurance was determined via bent-arm hang on a standard pull-up bar with hands in a pronated position (palms facing away from the body). Participants had 2 attempts with a 90 second recovery period between tests where time to absolute failure best time to fatigue was recorded from the two trials(Hermans et al., 2017).Dynamic muscular endurance fitness was determined as repetitions to fatigue at 50% of baseline 1-RM for bench press, prone leg curl, and seated leg extension strength. All repetitions were performed at a rate of 30 repetitions/minute (i.e. 60 beats per minute, with 1 beat for the "up" movement, and 1 beat for the "down" movement in each repetition). In addition a bodyweight squat testwhere total number of repetitions completed in 60 seconds was used to evaluate global lower body muscular endurance. A repetition was defined as standing stance to contact with a 9kg medicine ball with participants' buttocks (at the lowest point of the movement) with return to full standing position.

Lower body muscle power was determined via the countermovement vertical jump with a commercially available vertical jump test apparatus (Vertec; Columbus, OH). Two jump attempts (with one minute rest between attempts)was allowed and the best jump height was recorded(Burkett et al., 2005). A horizontal medicine ball toss from a seated position was used to assess the instantaneous upper body power of participants. A similar version of this test has been previously used as a measure of upper body power(Sobrero et al., 2014). As per previously prescribed protocols used to assess upper body power(Borms et al., 2016), the test involved pressing an8lb medicine ballhorizontally, as hard as possible. Following 2 practice attempts, each participant performed 2 throws (separated by 1 minute of rest) and the longest horizontal distance was recorded as the participant's best.

Statistical analysis

Aone-way ANCOVA statistical test (with baseline test-values as the covariate, training modality as the independent variable, and post-training test-values as the dependent variable) was usedto analyze differences in post-training meansin muscular strength, muscular power, muscular endurance, energy metabolism, and aerobic power outcomes between all study groups in the current experiment(while simultaneously controlling for differences in fitness between groups at baseline).When significance was detected, a Post-Hoc LSD test was used to discover the location of the significance (i.e. which two groups had significantly different post-training means) in the measured variable. Paired-samples T-tests were used to determine the pre-post change (i.e. baseline vs. post-training means) withinevery study group, for each of the aforementioned fitness outcomes. In all tests, the significance value was sets at $p < 0.05$; IBM® SPSS (Statistics Standard GradPack 23 for Windows) was the program used to perform all statistical tests in the current study.

Results

Participant descriptive variables including exercise historyand minutes spent exercising during the study are shown in Table 1. There were no significant differences in baseline variables between groups; however,HIFT participants were older and heavier than TRAD and FE groups (Table 1).All participants completed the study in either 49 or 50 daysand bodyweightdid not change over the course of the study (Table 1). Total exercise time or exercise time in moderate or vigorous intensity categories was not different between groups (Table 1).

Table 1. Participant descriptive background and overall training program data

		HIFT	TRAD	FE
Age Years)		24.5 ± 1.0*	23.5 ± 1.1*	21.6 ± 0.8
Pre-training bodyweight (Kg)		73.6 ± 3.1*	69.9 ± 3.1*	66.4 ± 3.0
Post-training bodyweight (Kg)		74.0 ± 3.1	70.65 ± 3.1	66.48 ± 3.1
Participants exercise history (Years)	**≤ 2**	5	3	4
	> 2	5	7	6
Pre-study exercise frequency (Days/Week)	**≤ 3**	6	4	4
	> 3	4	6	6
Pre-study HIFT experience	**Never**	7	6	9
	A few times	3	4	1
Number of supervised training sessions attended		15.0 ± 0.3	16.0 ± 0.5	0
Days between first day pre-training and last post training day		49.3 ± 1.0	49.2 ± 3.8	49.8 ± 2.6
Total time exercising during study (minutes)*		2606.4 ± 1186.3	1408.5 ± 158.2	1978.5 ± 188.1
Time performing moderate intensity exercise (min)		773.0 ± 389.6	446.3 ± 120.3	546.0 ± 122.4
Time performing vigorous intensity exercise (min)		1833.4 ± 826.6	962.2 ± 106.7	1432.5 ± 215.6

*All measures (other than bodyweight) were based on subjective answers to questions; all participant physical activity history was collected during the first day of baseline testing (prior to training initiation); exercise minutes were logged in daily or weekly training surveys where total exercise time includes exercise performed both during supervised training hours and outside of supervised sessions; moderate intensity exercise included any form of exercise in which participants felt they were working at a RPE of 4-6/10 includes; vigorous included any form of exercise in which participants felt they were working at a RPE of 7-10/10. There were no significant differences in exercise minutes or exercise time spent in each intensity category between groups; * significantly greater than FE group.*

Lower body 5 second peak power increased significantly in the FE group and 30 second mean anaerobic powerdecreased significantly in HIFT (-73.4 ± 22.8 watts, $p = .011$;Figure IA). Five second peak and 30 second mean upper body anaerobic power were not significantly different between groups training in any group; however,mean upper body power output (relative to pre study) did increase significantly in the TRAD group (Figure IA).Between group mean power output was lower in HIFTcompared to bothTRAD ($p = .025$) andFE ($p = .004$,as shown in Figure IB). Instantaneous power measured via medicine ball toss distance was not different between groups post study, but medicine ball toss distance was significantly increased post study in the FE group (17 ± 7 cm increase from pre – post study; Figure IC). Vertical jump height post study was not different between groups, but vertical jump height was significantly increased post study in the FE group (4.7 ± 1.9 cm increase from pre – post study; Figure IC).

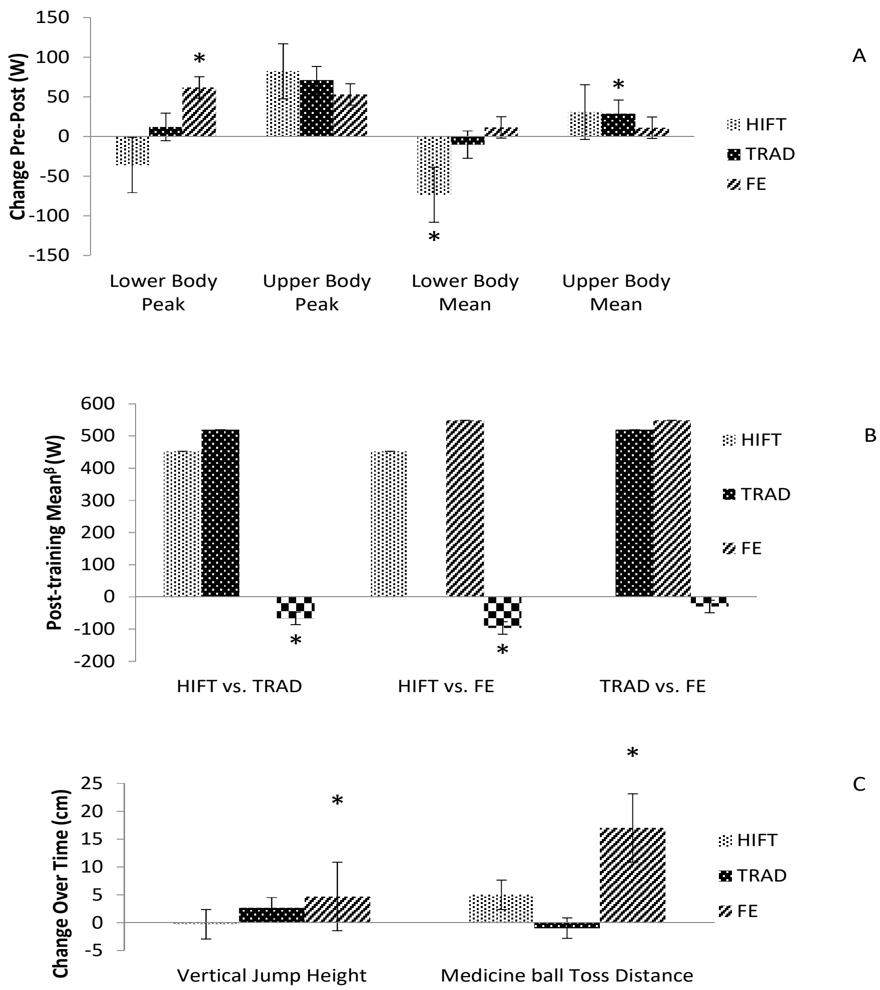


Figure I. Panel A shows within group change for peak power for both upper and lower body Wingate tests (Lower Body Peak and Upper Body Peak) and mean power for upper and lower body Wingate tests (Lower Body Mean and Upper Body Mean); *indicates change from baseline to post-training, $p < 0.05$, W = Watts. Panel B show between group comparison of post-training lower body mean power output during lower body Wingate testing; * indicates significant difference in post training values where between group differences in pre-training means were accounted for as the covariate$^{\beta}$, $p < 0.05$. Panel C shows within group difference between pre-post study for measures of instantaneous power where (vertical jump for lower body and seated medicine ball for upper body); * indicates

No between group differences were found in the maximalstage obtained during the shuttle run test, or the predicted VO_{2max}determined from the shuttle run test post-training. The HIFT group increased maximum shuttle run stage approximately 1 stage (mean of 0.9 ± 0.2, p= .00) which resulted in an estimated VO_{2max}mean increase of about 2.1 ± 0.8 ml/kg/min, p = 0.03.

No between group differences were found for post-training estimated 1RM of any strength measure. HIFT, TRAD, and FE all significantly increased barbell bench press, leg extension, pull-up, and leg curl estimated 1-RMs overtime, however barbell back squat only increased in the HIFT and TRAD groups (see Figure IIA).

Training had a positive significant effect on the number bodyweight squats performed in 1 minute in all groups, bent-arm hang times of HIFT and FE groups, as well a leg curl repetitions to fatigue in the TRAD group (see Figure IIB). There were no significant increases in any group for leg extension and barbell repetitions to fatigue from baseline to post study(see FigureIIB).
Post training between group differences in muscular endurance adjusted for differences in baseline values were found for both the upper and lower body. Specifically, bent-arm hang time for HIFT was 4.6 ± 1.9 seconds longer than TRAD and TRAD was 4.4 ± 1.9 seconds greater than FE (Figure IIIA). Leg extension endurance was increased by 6 repsin the HIFTand the TRAD groupcompared to the FE (see FigureIIIB).

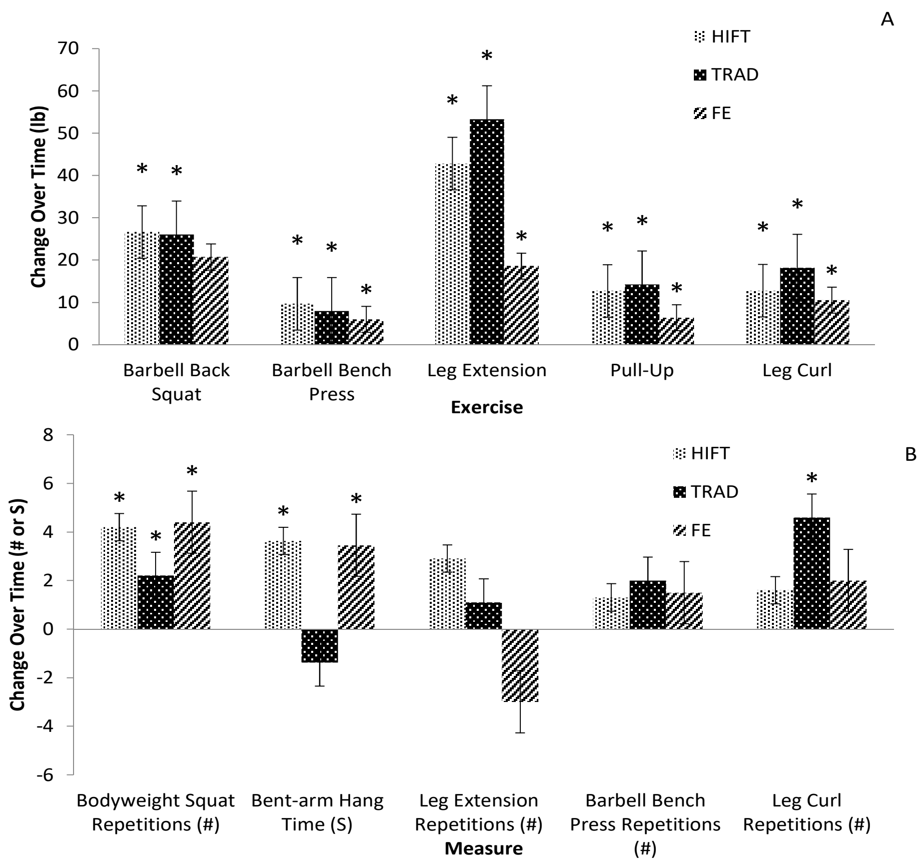
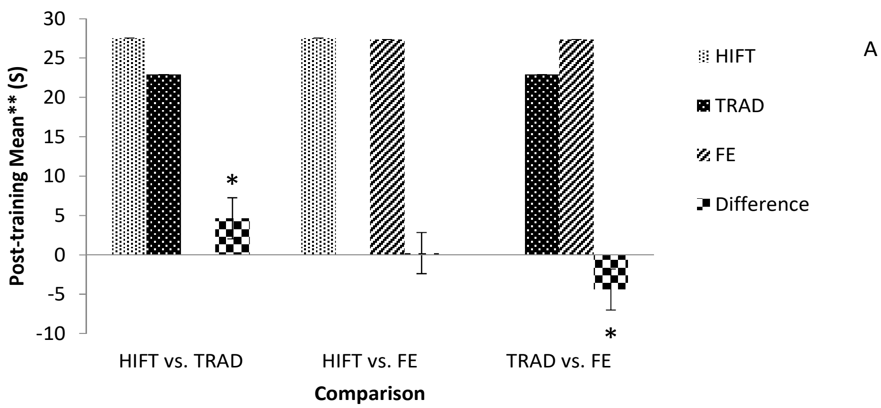


Figure II. Panel A is pre-post values 1-repetition maximum for back squat, bench press, leg extension, leg curl, pull up. All values expresed as predicted 1RM in lbs where * indicates significant difference between pre and post training ($p < 0.05$). Panel B is pre-post values for muscle endurance assessments. Leg extension, barbell bench press, and leg curl exercises were performed to failure using 50% of the baseline estimated 1-RM for each respective exercise at a pace of 30 repetitions (60 beats) per minute; the maximum number of repetitions performed using this protocol are reported as numbers (#) in the above figure. Bodyweight squats were performed as quickly as possible to a fixed height (an 8lb slam ball); the maximum number of repetitions (performed in 60 seconds) using this protocol are also reported as numbers (#). The bent-arm hang exercise was held continuously, in a single repetition to failure measured in seconds. * indicates significant difference between pre and post training ($p < 0.05$).



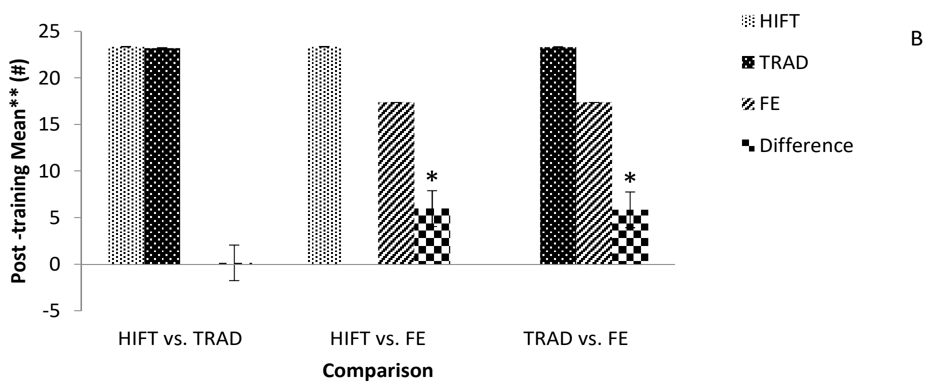


Figure III. Panel A is between group differences in post-training bent-arm hang time to failure measured in seconds. Panel B is between group differences in post training leg extension repetitions measured in repetitions. * denotes significant difference ($p < 0.05$) where ** indicates adjusted for between group differences in pre-training means (as the covariate).

Discussion

Advocates of HIFT(Glassman, 2010)promote the benefits of this type of resistance training as beneficial to all aspects of fitness however limited research has compared HIFT to other types of training(Barfield et al., 2012; de Sousa et al., 2016; Jeffery, 2012). Thus, we aimed to compare what specific fitness adaptations might be significantly improved with a varied HIFT training program approach that is popular in the fitness industry,compared to traditional resistance training. We had hypothesized that HIFT based on previous research would have a significantly greater effect on anaerobic and aerobic metabolism. We did find a small but significant increase in aerobic power compared to TRAD and FE however mean lower body anaerobic powerwas significantly less compared to TRAD and FE post training. The anaerobic fitness results were surprising and reasons for this finding are discussed in detail below. Contrary to our hypothesis TRAD training provided no significant improvements in muscle endurance, strengthand power relative to HIFT.From one perspective these results support the idea that healthy adults can engage in HIFT training and see similar benefits across a range of health related components of fitness(Garber et al., 2011) compared to traditional resistance training. Specific aspects of our findings are discussed in further detail below.

Firstly, we think that specificity as a training principle might explain some results. It is understood that whentraining to improve a specific metabolic pathway (anaerobic or aerobic) the duration and intensity should target that metabolic pathway as specifically as possible(Isratel et al., 2016). In our study the durations of some workout circuits in the HIFTgroup were 20 minutes of continuous work which would be more aerobic than anaerobic(Coffey & Hawley, 2007)in nature. Thus the specificity as a training principle likely contributed to the small mean increase (2 ml/kg/min) in HIFTaerobic power post training where 7 of the 10 HIFT participants improved. Previous studies(Farrar et al., 2010; Fernández-Fernández et al., 2015) would also support this conjecture where commercially available HIFT programs and exercises tend to elicit an aerobic intensity that meets or exceeds the minimum requirements to improve cardiorespiratory fitness (i.e. 60 - 85% VO2max, according to the ACSM) (Garber et al., 2011). However, these results might be interpreted with caution because the HIFT aerobic power gain was not different than TRAD when comparing post training values similar to previous research comparing HIFT to TRAD training (Barbieri et al., 2019). In fact 3 TRAD participants also increased aerobic power (5 stayed the same and 2 went down), thus our results are not definitive in saying HIFT is superior to TRAD training in improved VO_{2max}. Previous research has also illustrated that high repetition (20–28 RM) short duration rest (1 min) exercise programs can also improve VO_{2max}(Campos et al., 2002). This previous finding would fit with our exercise protocols where the TRAD group had some double drop set exercises where 20-30 reps for specific exercises was completed. So it may be the case that high repetition muscle endurance type workouts (of which both our TRAD group had and our HIFT group had on specific days) provide sufficient aerobic stimulus to see gain in aerobic fitness.

Our results indicate that HIFT training did not improve lower body anaerobic alactic and lactic power fitness despite previous research(de Sousa et al., 2016; Jeffery, 2012)which indicates HIFT engages significant anaerobic dependent metabolism. In fact lower body peak and mean power output decreased pre – post (Figure IA) and lower body mean power was significantly less than TRAD and FE post training (see Figure IB). Furthermore, TRAD lower body mean power was also less post training with a negligible increase in lower body peak power (see Figure IA). These TRAD results are also surprising given the purported benefits of resistance training on anaerobic power fitness(Arslan, 2005). Thus, further introspection is required to explain these results. The principle of recovery may shed some light on our present results where lack of recovery can lead to significant underperformance despite adequate training overload(Budgett, 2000). In fact lack of recovery likely influenced performance in both training groups (i.e. HIFT and TRAD) especially those aforementioned measures above. Practically speaking we did plan for a recovery period of 3 days to address the influence of fatigue as per recommendations for high intensity assessments(Bishop et al., 2008)however this may have not been enough. Anecdotally, some participants in both TRAD and HIFT groups reported feelings of "dead legs" or legs "feeling like concrete" and previous research has found these sorts of lower body feelings require 7 days of easy activity(Halson et al., 2002) before performance impairments are resolved(Myrick, 2015). Others have also reported accumulated fatigue as a factor for decrements in performance following short-term HIFT type training(Drake et al., 2017)although this was related to VO_{2max} performance rather than anaerobic power.Nevertheless, our study findings would suggest that both monitoring participant fatigue and extending the rest period beyond 3 days are important considerations to obtaining optimal post training performance assessments. Furthermore this recommendation could be applied to real world situations where exercise specialists and trainers mightconsider extending rest beyond 3 days post training block or program before re-assessing fitness.

Specificity as a training principle may also explains the increase in upper body pull endurance postHIFTcompared to TRAD (see figure IIIA). Specifically, when compared to TRAD participants, HIFT performed different durations, intensities, and types of upper body pulling exercises which were similar to bent arm hang exercises (such as pull-ups or assisted pull-ups). TRAD on the other hand performed isolated, machine based vertical pull-down and horizontal row type exercises with no suspended or free hanging exercises. The idea that practicing a similar type exercises will improve muscle strength and performance in a task has been termed "task specificity"(Stone et al., 2000) and these results might reflect this idea. Task specificity, has been illustrated in other training studies where pull-up endurance (i.e. maximum number of pull-ups performed in 1 minute) was improved more than other measures of upper body muscle endurance by replicating that same exercise in training(Barfield et al., 2012).

From an efficacy standpoint, our results indicate that 15 sessions of either HIFT or TRAD training can significantly improve muscle strength in the upper and lower body (see Figure IIA)in healthy adults however there were no distinguishing differences between groups post training (the exception being upper body pull endurance and leg extensions to fatigue (Figure IIIA and 3B). Our conclusions should be considered carefullyhowever, due to the improvements in muscle strength and endurance in the FE groupwhich may indicate a learning effect. Other resistance training studies of similar length found no change in their control group for vertical jump (Maroto-Izquierdo et al., 2019), or grip strength(Kobesova et al., 2015) however the number of resistance training studies that have used a control group is very small. In fact lack of control groups is an ongoing methodological concern as highlighted previously in a major review of strength gains in athletes(Hartmann et al., 2015) whereby including controls in resistance training studies is recommended. We would support the idea that adding free exercise groups like we did in our study improves the true magnitude of the training effect. We also want to highlight that our study is the first HIFT training study to utilize a FE group and that in our study the use of a control group allowed us to conclude that a learning effect might have influenced the lack of difference between groups post training.

We also wanted to present some physiological underpinnings for why we think similar results were found in both TRAD and HIFT groups borrowing from literature in the subcellular exercise physiology domain. It is understood that healthy untrained individuals who engage in strength and/or aerobic trainingwill cause a large disruption in cellular homeostasis in such individuals(Benziane et al., 2008) compared to fitter individuals. Furthermore this cellular disruption has been described as creating a "generic molecular footprint" which upregulates processes of adaptation regardless of the mode of physical activity(Coffey & Hawley, 2017). Our results would support this idea where similar gains post training were found in the TRAD and HIFT groups, although we acknowledge that we did not measure any specific biomarkers to illuminate cellular markers of adaptation. However, we still feel it's instructive to present some physiological reasoning for the similar improvements in groups, especially to inform future research in this area.

From a program design standpoint a few points should be made. First, ourstudy indicates that neither total training volume nor time spent doing either moderate or vigorous activity (see Table 1) influenced results. As advocated by exercise guidelines progressive overload can be achieved via increased duration where more minutes completed should see greater adaptation gains(Garber et al., 2011). However, as found in Table 1 despite lower minutes for the TRAD group similar improvements in muscle strength and endurance were found compared to HIFT. Some of the variation in accumulated minutes between groups may be due to habitually different levels of physical activity for individuals assigned to a group (i.e. the TRAD group individuals just did less in general) however it might also be related to the mode of activity. To elaborate, it might be that those engaged in a TRAD type program felt they needed more recovery and did less outside of the supervised sessions. We did not complete an outtake survey to confirm this; however we would offer this an opportunity for future research to look at how modes of resistance training can influence general physical activity levels. Looking at other aspects of training pattern in our participants, training logs indicate that additional non–supervised exercise which was accumulated between supervised exercise days might have affected recovery between training sessions. This additional training likely influenced energy and motivation during supervised sessions and in retrospect we would have recommended no activity to improve recovery. This approach of days off would also allow an easy-hard training pattern which is well known to improve energy on training days and reduce monotony leading to overtraining(Foster et al., 2001).

Conclusions

In conclusion, HIFT training that utilizes a high degree of inter-day variability in the delivery of workouts has a positive effect on muscular fitness as shown by increased upper body push strength, upper body pull strength, leg extension strength, leg flexion strength, lower body general strength and lower body general endurance in recreationally trained adults.However, the magnitude of the fitness gains is not different from traditional style resistance training workouts (TRAD group) and/or a non-specific exercise plan as shown in the FE group. Thus, it is unclear if a HIFT approach offers any additional benefits that cannot be gained via traditional resistance training on the main health related components of fitness(Pollock et al., 1998). We would offer that the lack of differences post training may have been due to the large intra-group variability which concealed the intervention effect thereby limiting some of the potential post training group differences we hypothesized. We also cannot ignore how fatigue likely contributed to reduced anaerobic fitness and that fatigue was both due to under recovery as well as high school stress, as most participants were University students participating in the second half of the fall semester. This would be a cautionary point for other researchers to accommodate school stress and also pay attention to the timing of recruitment so as to reduce school stress points (like end of term). Yet despite some limitations our results would recommend that adults might engage in different modes of resistance training and see similar gains in fitness. Thus, letting the client decide which type of training they enjoy more could improve client motivation and satisfaction while still achieving gains in fitness.

Conflicts of interest: The authors have no conflict of interest to declare.

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