



HAL
open science

Physical Fitness Responses after Sixteen Weeks of Three Fitness Program Trainings in Untrained Subjects

Habil Hamdouni, Brian Kliszczewicz, Hassane Zouhal, Abderraouf Ben Abderrahman

► To cite this version:

Habil Hamdouni, Brian Kliszczewicz, Hassane Zouhal, Abderraouf Ben Abderrahman. Physical Fitness Responses after Sixteen Weeks of Three Fitness Program Trainings in Untrained Subjects. *International Journal of Exercise Science*, 2024, 17 (4), pp.54-72. hal-04577654

HAL Id: hal-04577654

<https://hal.science/hal-04577654>

Submitted on 16 May 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License



Original Research

Physical Fitness Responses after Sixteen Weeks of Three Fitness Program Trainings in Untrained Subjects

HABIL HAMDOUNI^{1,2†}, BRIAN KLISZCZEWICZ^{3‡}, HASSANE ZOUHAL^{4,5‡}, and ABDERRAOUF BEN ABDERRAHMAN^{1,2‡}

¹Higher Institute of Sport and Physical Education of Ksar - Said, Maniuba, Tunisia, Africa; ²Tunisian Research Laboratory 'Sports Performance Optimization' (LR09SEP01), National Center of Medicine and Science in Sports (CNMSS), Tunis, Tunisia, Africa; ³Kennesaw State University, Department of Exercise Science and Sports Management, Kennesaw, GA, USA; ⁴M2S, Laboratoire Mouvement, Sport, Santé, EA 1274, Université Rennes, Rennes, France; ⁵Institut International des Sciences du Sport (2I2S), Irodouer, France

[†]Denotes graduate student author, [‡]Denotes professional author

ABSTRACT

International Journal of Exercise Science 17(4): 54 - 72, 2024. The remarkable popularity of fitness trends like high intensity functional training (HIFT), choreographed high intensity classes (CHIC) and resistance (RT) trainings raises the question on their effect on cardio-respiratory, lactate removal rate, endurance and body composition responses. The purpose of this study was to assess and compare these effects. Ninety-five participants were randomly assigned into 16 weeks of these trainings, five sessions/week. Anthropometric and fitness tests were carried out before training (PRE), after eight (8W) and sixteen weeks (16W). Body composition measures demonstrated significant decrease in body fat percentage ($p < 0.001$, $d = 0.17-0.54$) for all groups and fat mass ($p < 0.001$, $d = 0.26-0.53$) for HIFT and CHIC in 8W, 16W and in 16W for RT ($p = 0.03$, $d = 0.14$), also significant increase in fat free mass only in HIFT ($p < 0.002$, $d = 0.06-0.21$) and RT ($p < 0.001$, $d = 0.17-0.33$) in 8W, 16W. Cardio-respiratory measures demonstrated significant improvements in maximal aerobic capacity for HIFT ($p < 0.001$, $d = 0.58-1.26$) and CHIC ($p < 0.001$, $d = 0.45-1.21$) in 8W, 16W. Endurance tests demonstrated significant improvements in 8W, 16W in aerobic endurance among HIFT ($p < 0.001$, $d = 1.28-3.19$) and CHIC ($p < 0.001$, $d = 1.16-1.79$), in muscle absolute endurance in three groups ($p < 0.002$, $d = 0.14-1.17$) and muscle relative endurance in HIFT ($p < 0.02$, $d = 0.13-0.2$) and RT ($p = 0.03$, $d = 0.3$) in 16W. We can conclude that HIFT and CHIC are effective for cardio-respiratory and endurance improvement and all three programs are effective in reducing body fat

KEY WORDS: training, organic responses, HIFT, stamina, lactate

INTRODUCTION

In recent years the number of fitness centers available to the general public has greatly increased, with more than 210,000 locations worldwide, and catering to over 183 million members (24). According to previous studies, commonly sought goals of fitness center members are physical

wellness, improved fitness, and weight loss (39). However, the manner in which these goals are achieved vary, with fitness centers providing increasingly diverse services aimed towards achieving these goals (25). Advancements in technology and equipment has led to fitness industries adapting to provide the most appealing forms of exercise to their clientele. In an attempt to better understand and track industry interests, an annual worldwide survey lists the top 20 fitness trends (44, 45). Numerous commercial and non - commercial fitness programs have been created to address these trends, perhaps the most widely available are high intensity functional training, choreographed high intensity classes and resistance training.

High intensity functional training (HIIFT) has experienced rapid growth since 2000 especially in the form of commercial programs. HIIFT can best be described as a constantly varying functional movement executed in a high intensity patterns that blends different techniques of weightlifting (e.g., clean, snatch, deadlift, etc.), gymnastics (e.g., push-ups, pull-ups, sit-ups, etc.) and endurance movements (e.g., running, rowing, swimming, etc.) in the same training session called workout of the day (WOD), which can be bouts of less than 12 minutes or session up to 50 minutes (8, 9). On the other hand, choreographed high intensity classes (CHIC) is a more established presence in the fitness industry, for instance one commercial program subscribed more than 20,000 affiliates worldwide (26), that is known as the largest producer of pre - choreographed exercise classes (10). Briefly, CHIC is a form of high - intensity training that is choreographed to music of different themed classes, which range in techniques (stepping, jumping, kicking, punching, weight lifting, and cycling) in order to deliver comprehensive workouts that last from 45 to 55 minutes (10). Lastly, resistance training (RT) is resistance - based programming focused on the execution of progressive resistance exercises targeting large muscle groups with the goal to increase strength and/or muscle size. Progressive RT is performed by using weighted bars, dumbbells or machine stations, at controlled weights (22, 31).

Each program has demonstrated various favorable adaptations following training as they relate to cardiovascular fitness (capacity and endurance), muscular fitness (relative and absolute), and body composition (5, 11, 18, 41). For instance, HIIFT has been demonstrated to increased VO₂max and improvements in body composition (32); However, several of these studies demonstrate variable (35) if not conflicting (6, 41) results. Similarly, RT has shown great improvements in body composition along with muscular fitness (11) and even in some cases cardiovascular endurance (18). Currently, CHIC related research is limited, likely due to the changing variety of classes as well as the difficulty in reproducible protocols being observed outside of a lab. Therefore, the purpose of this project is to compare and contrast changes, if any, in measures of cardiovascular fitness (capacity and endurance), muscular fitness (relative and absolute), and body composition over 16 weeks between HIIFT, CHIC and RT interventions on sedentary subjects.

METHODS

Participants

The Human Research Ethics Committee of the University of Manouba, Tunisia approved all tests and protocols in this study and are in accordance with the Declaration of Helsinki along with the ethical standards of the International Journal of Exercise Science (34). Participants were recruited via word of mouth or online flyers (in Tunis city). A total of 147 participants were recruited, 120 met eligibility criteria, and 95 completed the interventions (Figure 2). Inclusion criteria for this study were recently inactive (not achieving moderate/vigorous physical activity threshold of 75–150 min/week over a three month period (38)) males and females with no known cardiovascular, pulmonary or metabolic disorders, and no muscle, tendon, or bone related injury that would limited that participants ability to perform exercise. Exclusion criteria were presence of any type of illness, suffering from cardiac, muscular and/or neurological disorders and doing other types of training or not respecting the minimum number of sessions/week. Before the study began, participants were provided detailed information regarding the benefits, risks and requirements of the study, and provided the opportunity to ask any questions prior to signing an informed consent. Participants were then randomly assigned to three groups: (HIFT) High Intensity Functional Training ($n = 31$), (CHIC), Choreographed High Intensity Classes ($n = 30$) and (RT) Resistance training ($n = 34$).

Age and anthropometric parameters for all groups are presented in Table 1. Height and weight were measured with an electric scale InBody 770 (Inbody USA, Cerritos, CA, USA), all measurements were carried out by an expert investigator.

Protocol

All data collection occurred in the Exercise Science Laboratory. Prior to their first lab visit, participants were assigned to one of the following groups: HIFT, CHIC, or RT. Participants were asked to arrive to the lab for three separate periods throughout the 16 - week intervention: orientation and pre intervention (PRE), mid-intervention (8 weeks) (8W) and post intervention (16 weeks) (16W). Each visit occurred between 7 a.m. and 9 a.m. Each period (PRE, 8W, 16W) consisted of four sessions, occurring 48 - hours apart, within a 7 - day period (Figure 1). This first visit of each period included body composition and estimated maximal aerobic capacity followed by lactate assessment. The second visit included absolute muscular endurance for upper and lower body. The third visit included relative muscular endurance for upper and lower body. The fourth and final visit consisted of an aerobic endurance test performed at maximal aerobic speed (MAS), obtained on visit 1. Participants were verbally encouraged throughout the testing protocols. Following PRE, participants began their assigned 16 - week intervention. The workouts designed for this study were carried out in three different fitness centers, each center followed requirements of safety (e.g., emergency, first aid) and hygiene (e.g., controlled temperature, clean environment). Participants were allocated to train for five times a week (5 days of training, 2 days of rest). Lab conditions are set to inside the laboratory where the temperature was set at 23°C and ambient humidity around 60%.

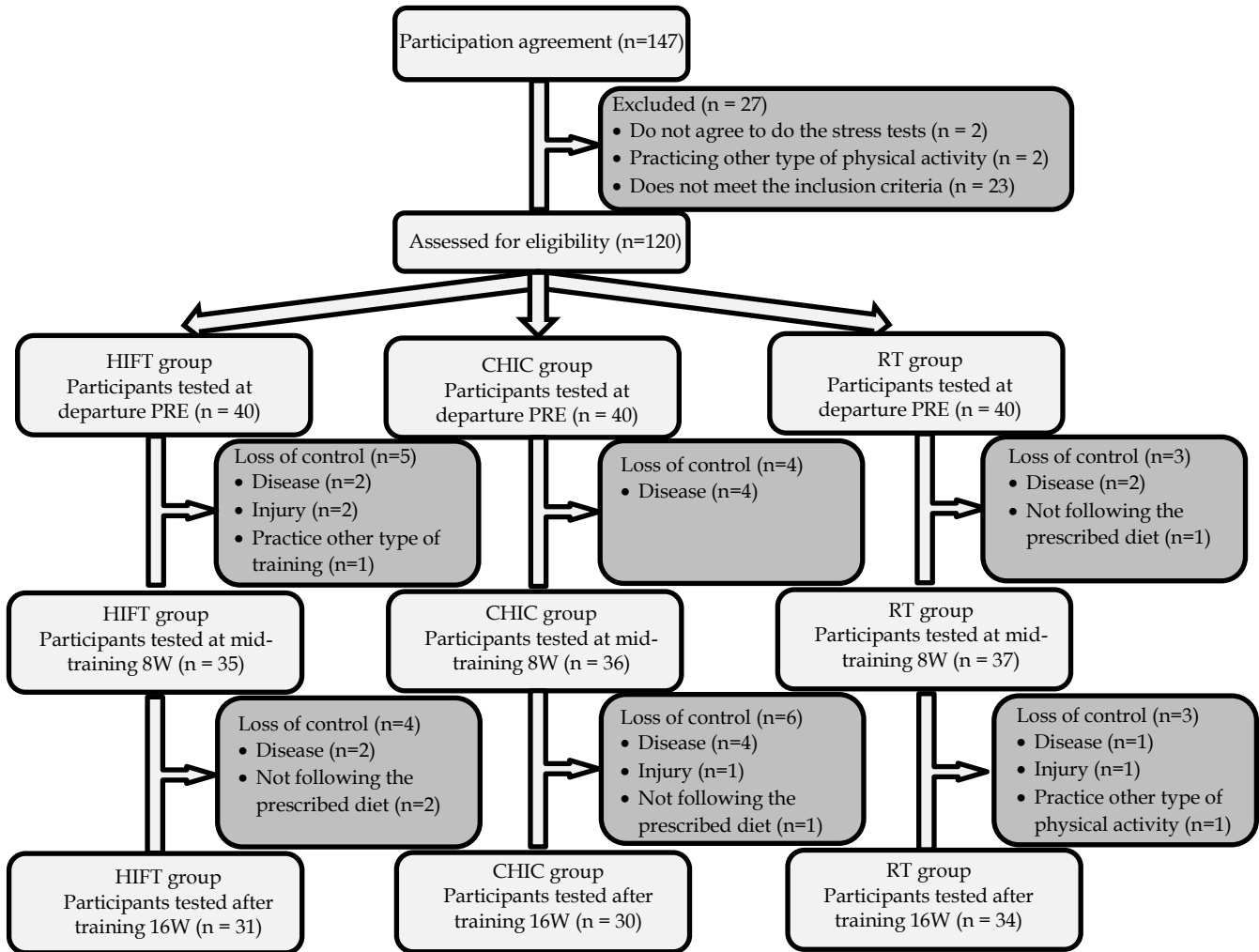


Figure 1. Flow of participants during the study. HIFT = High intensity functional training; CHIC = Choreographed high intensity classes; RT = Resistance training

Table 1. Basic anthropometric characteristics of all groups.

	HIFT (n = 31)	CHIC (n = 30)	RT(n = 34)
Men	22	23	26
Women	9	7	8
Age	31.5 ± 5.6	28.8 ± 7.8	33.1 ± 9.5
Weight (kg)	78.4 ± 14.6	75.3 ± 11.9	81.1 ± 8.5
Height (cm)	175.9 ± 11.7	179.9 ± 15.4	172.6 ± 13.2
BMI (kg.m ⁻²)	25.1 ± 9.8	23.9 ± 5.3	27.5 ± 4.4

Note: BMI = body mass index. Data are presented on average ± standard deviation.

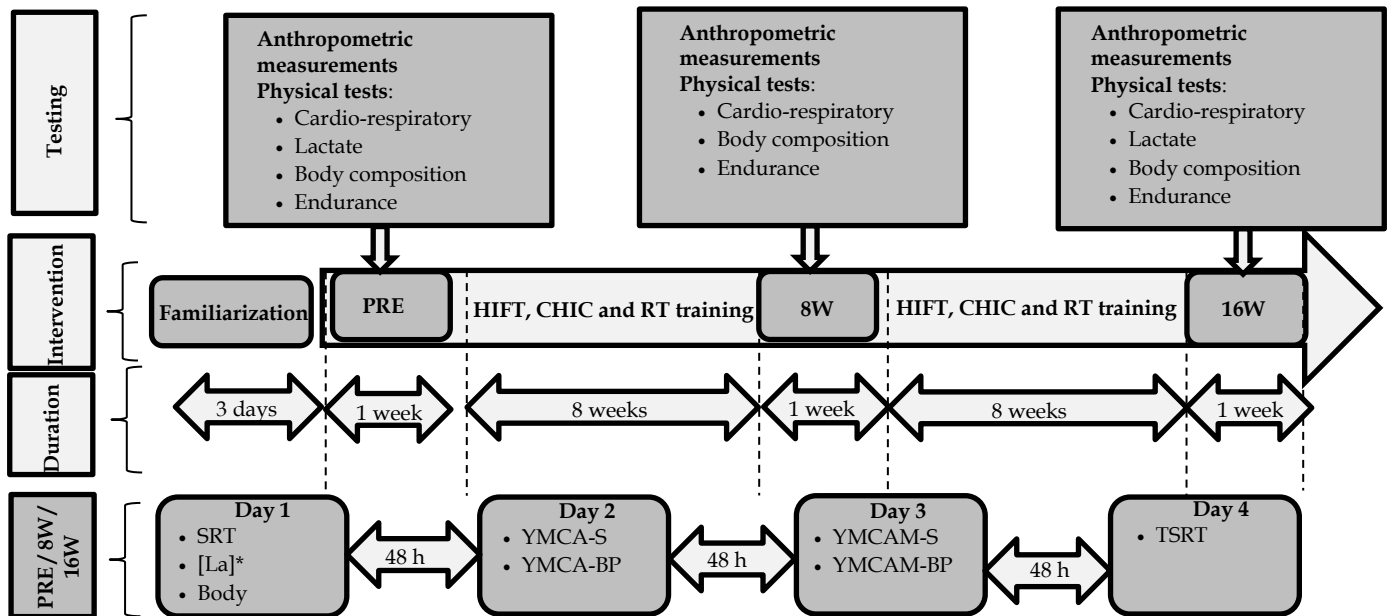


Figure 2. Representing the different study and test sessions. HIFT = High intensity functional training; CHIC = Choreographed high intensity classes; RT = resistance training; * = except for 8W; S = squat; BP = bench press

The training of HIFT took place in a specialized and affiliated HIFT gym with certified coaches and the programming of the WODs were carried out according to a commercial HIFT program (6, 8, 9, 12, 32, 41). Session started with a light warm - up and dynamic stretching (10–15 min) followed by a specific warm - up to prepare participants for the main techniques of the WOD (10–20 min), then participants started the main WOD (20 - 30 min) which consists of executing functional techniques inspired from weightlifting (Clean and Jerk, Snatch, Squat, Bench Press, Deadlift, Swings), gymnastics (Pull - up, Dip, Push - up, Handstand, Muscle up (rings, bar), Pistol,) and endurance sport (running, cycling, rowing) instructed by time domain restrictions such as 'For time, EMOM (every minute on the minute), AFAP (as fast as possible) or repetitions requirements such as Unbroken (nonstop), AMRAP (as many rounds as possible), and finally a cool - down and stretching part (5 min). Whatever the time of day, participants followed training for five times a week.

The training of CHIC took place in a fitness facility that is affiliated in a commercial choreographed classes program (10, 13). CHIC training was provided by certified instructors using supports (Videos, Audios and Script) and classes followed in this study were similar in Hamdouni H, et al 2022 (12). Sessions were executed between 45 and 55 minutes of cardiovascular interval training that combines high intensity aerobics, strength and stabilization exercises synchronized with music and inspired whether from an array of martial arts disciplines (karate, boxing, Taekwondo, and Muay Thai), from athletic movements (jumping, running), from strength exercises (using barbells and adjustable weights) or cycling discipline

combining bouts of sprints and hill climbs. Likewise, the weekly training was followed through five different classes.

Participants were asked to follow a personalized RT program based off their pre - testing performance (i.e. resistance intensities), 5 times/week, each time targeting a single muscle group. In each training session the participant begins with the multi - joint exercises and progresses to the single - joint exercises (22) with slow execution: 2 s concentric phase and 2 s eccentric phase (2: 2), and with a rest time of 50 s between sets and 120 s between exercises. The load chosen for each exercise was relative to the one repetition max. Each RT session targeted a single muscle group: Pectoral muscles, posterior chain, legs, shoulders and finally arms and abdominals. Before each session, a warm - up was performed to prepare the body for the next stimulus involving the targeted muscle group. All training sessions were supervised by professional trainers. An example of the RT program is presented in Table 2.

Table 2. Training used in the traditional resistance training group

Training day	Exercises	Total sets
Day 1: Pectoral	Bench press, Dumbell Incline Press, Dips, chest press, Cable Incline Chest Fly*, Machine Chest Fly*, Dumbell Pullover	23
Day2: Posterior chain	Deadlift, Machine Back extension, Single arm machine pull down, Weighted pull up, Single arm machine horizontal pull, Low pulley, Cable straight arm pull down*	22
Day 3: Legs	Squat, Lunges, Leg press, Leg extension, Leg curl*, Weighted hip thrust, Seated calf raise*	23
Day 4: Shoulders	Barbell Shoulder Press, Single Arm Arnold Press, Barbell Upright Row *, Clean press, Lateral raise*, Frontal raise*, Rear Delt Fly, Barbell Shoulder Shrug	28
Day 5: Arms and abdominals	Cable biceps curl, Dumbbell hammer curl, Cable triceps extension, Dumbbell over - head extension, Reverse curl, Barbell wrist curl, Weighted crunches, Cable Russian twist	24

Note: Unless indicated otherwise, each exercise was performed in 3 sets (loads are percentages of one repetition maximum): 10 repetitions at 70% load, 8 repetitions at 80% load, 6 repetitions at 90% load. *4 sets: 14 repetitions at 60% load, 12 repetitions at 70% load, 10 repetitions at 80% load, 8 repetitions at 90% load.

During the study period, participants were instructed to follow a strict diet and to report the use of any type of medications, the goal was to have a healthy and balanced diet of macros and micronutrients (19) in order to avoid habits that could bias the results of the study and to have the same conditions between participants, three nutritionists monitored the diet of the participants by informing them of the quality and quantity of their diet at the start of each week while respecting individual favorites. Table 3 represents the daily food intake of each participant.

Table 3. Dietary intake during the study period

Nutrients	Real Intake	Relative intake
Energy	25-35 kcals/kg/day	1800-2400 kcals/day
Carbohydrates	5-8 g/kg/day	45-55%
Protein	1.4-1.8 g/kg/day	15-20%
Lipid	2.0-2.5 g/kg/day	25-35%

Vitamins	115-130 mg/day	0.4-0.6%
Minerals	4500-4600 mg/day	0.4-0.6
Cholesterol	150-200 mg/day	3-4%
Fiber	25-38 g/day	3-4%

Cardio-respiratory Fitness Measures (Estimated VO_{2Max}): The 20m shuttle run test (SRT) was used to estimate the maximum aerobic consumption (VO_{2Max}) (23). Two parallel lines were drawn 20 meters from each other, participants had to run between these two lines in cadence to the rhythm of a prerecorded metronome with progressively increasing rates. Each metronome beat indicates the instant when the participant had to reach one of the lines, the running speed started at $8.5 \text{ km} \cdot \text{h}^{-1}$ and increased with $0.5 \text{ km} \cdot \text{h}^{-1}$ each one minute. Participants were instructed to follow the rhythm of the metronome for as long as possible. The test concluded when participants fail to touch the line on cadence twice in a row or volitional fatigue. Predicted VO_{2max} was calculated by applying the number of completed shuttles (TL), to the Matsuzaka regression equation ($VO_{2max} = 42.4 - (2.85 \times \text{gender}) - (0.488 \times \text{BMI}) + (0.247 \times \text{TL})$; male = 0, female = 1) (27,28) Immediately following the SRT blood lactate [La] was taken via finger stick using a lancing device. Participant's finger was disinfected on the sampling area with cotton swabs soaked in alcohol, the first drop of blood was wiped off, afterwards, the lactate was measured using a portable lactate analyzer Lactate Pro 2 (Arkray®, Japan). Seven time points were recorded for [La] immediately after SRT test, and every 3 minutes until the 18th minute (0,3,6,9,12,15,18 minutes after the SRT test).

The time to exhaustion (T_{lim}) shuttle run test (TSRT) was used to measure cardio-respiratory endurance (1). This test occurred on visit 4 of PRE, 8W, 16W (Figure 1) using information provided by the SRT test. The TSRT consisted of a 20 m shuttle run test performed at 100% of the maximal aerobic speed (MAS) measured during the SRT test. Participants were instructed to run as long as possible at a pace corresponding to their MAS, which was prompted by a metronome programed to the corresponding speed of the MAS.

The YMCA test was used to measure absolute muscular endurance of the participants for upper and lower body (20). Two techniques were used; Bench press (BP) to assess the upper body and Squat (S) for the lower body. For both BP and S, the participants were instructed to perform repetitions at a cadence of $30 \text{ reps} \cdot \text{min}^{-1}$ with a bar loaded with 36.4 kg (80 lb) for men and 15.9 kg (35 lb) for women. Prior to testing, participants familiarized themselves to the metronome cadence. The participants were asked to perform the test respecting the range of motion and without bouncing the bar, and the test was terminated when the subject could no longer lift the bar or could not maintain the pace.

The modified YMCA (YMCAM) test was used to measure for relative endurance (2). The participants were instructed to repeat the same tests (BP and S) at a cadence of $40 \text{ reps} \cdot \text{min}^{-1}$ with the bar loaded with 40% of their own 1RM (load corresponding to a maximum repetition) already assessed in the familiarization and prior to 8W and 16W evaluations (participant performed series of a single repetition with a gradually incremented load (2.5-5kg) from 90% estimated until failure with a 3 min recovery between attempts, in case of failure the last load lifted was recorded). Prior to testing, participants familiarized themselves to the metronome

cadence. The participants were asked to perform the test respecting the range of motion and without bouncing the bar, and the test was terminated when the subject could no longer lift the bar or could not maintain the pace. For both YMCA and YMCAM, tests were scored by the maximum number of repetitions that each subject was able to perform.

Body composition was assessed through bioelectrical impedance analysis (BIA) method using the multi - frequency bioelectrical impedance InBody 770 (Inbody USA, Cerritos, CA, USA). For proper measuring participants were fasting (on an empty stomach for at least 4 hours) (29). Prior to measurement, participants were asked to remove their shoes and socks and then instructed to wipe the bottoms of the feet and palms of the hands using tissue that contained 0.9% NaCl. Participants were then asked to step onto the BIA device, placing the soles of their feet on the foot electrodes and gripping the hand electrodes. The participant was asked to stand with their arms straight and away from the trunk so they were not touching the body to achieve proper testing posture according to the manufacturer's guidelines. The InBody 770 device estimates body fat percentage (BF%), fat free mass (FFM), fat mass (FM) and Total body water (TBW), using six different frequencies: 1 kHz, 5 kHz, 50 kHz, 250 kHz, 500 kHz and 1000 kHz.

Statistical Analysis

The data were analyzed with the statistical program SPSS version 26.0 for Windows (SPSS Inc., Chicago, USA) and the statistical significance level was established at $p < 0.05$. Descriptive statistics are presented as means \pm standard deviations. All data were normally distributed, and this was assessed by the Shapiro-Wilk test. The homogeneity of the variances was confirmed before analysis using the Levene test. Single factor analysis of variance was used to verify the non - existence of statistically significant differences in pre-intervention measures (PRE). Likewise, three types of analysis of variance were used to assess the training effect; the first, 3×2 two-factor analysis of variance for the evaluation of [La], the second, 3×3 repeated measures mixed analysis of variance for SRT and TSRT tests, and the third is a multivariate analysis of variance for muscular endurance and body composition results. In addition, the Bonferroni post-hoc test was used to determine the importance of the improvement between the different measures and to compare the changes between the different training sessions. Finally, the size of the effect of the differences between variables effects was interpreted by the calculation of the partial eta-square η_p^2 and effect sizes (ES) for pairwise comparisons were calculated as Cohen's d where appropriate (7). An effect size < 0.2 indicates a negligible difference, between 0.2 and 0.5 a small difference, between 0.5 and 0.8 a moderate difference and greater than 0.8 a large difference.

RESULTS

Single factor analysis of variance did not show any significant difference between groups in PRE measurements whether for different tests or anthropometric characteristics ($p > 0.05$). The analysis of variance of the SRT test results showed a significant interaction time \times group ($F(2,91) = 37.6$, $p < 0.001$, $\eta_p^2 = 0.45$), a significant difference between times ($F(2,91) = 223.83$, $p < 0.001$, $\eta_p^2 = 0.71$) and between groups ($F(2,91) = 5.7$, $p = 0.005$, $\eta_p^2 = 0.11$) (Figure 3). The post

hoc test showed significant increase in the values of VO_{2max} for HIFT ($p < 0.001$, $d = 0.58-1.26$ [moderate-large]) and CHIC ($p < 0.001$, $d = 0.45-1.21$ [moderate-large]) every eight weeks. For the difference between groups the same test showed a significant increase in VO_{2max} of CHIC compared to RT group ($p = 0.008$, $d = 0.84$ [large]) at 8W, and a significant increase in VO_{2max} of CHIC ($p < 0.001$, $d = 1.63$ [large]) and HIFT ($p < 0.001$, $d = 1.18$ [large]) compared to RT group at 16W.

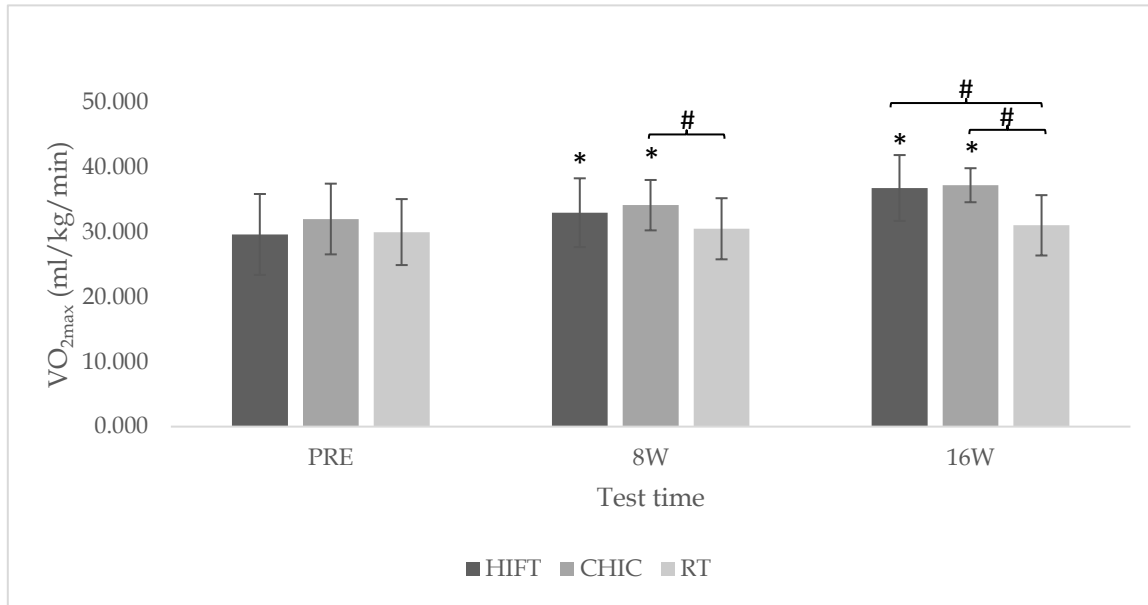


Figure 3. Histogram of the results after the SRT tests measurements. * = Significant intra-subject difference at $p < 0.05$ compared to the previous measurement, • = Significant intra-subject difference at $p < 0.05$ compared to the first measurement, # = Significant inter-subject difference at $p < 0.05$, PRE = Pre-training, 8W = 8weeks, 16W = 16 weeks, HIFT = High intensity functional training; CHIC = Choreographed high intensity classes; RT = resistance training.

The analysis of lactate values showed significant differences between times [($F(1,91) = 10.32$, $p = 0.002$, $\eta_p^2 = 0.10$); ($F(1,91) = 9.57$, $p = 0.003$, $\eta_p^2 = 0.09$); ($F(1,91) = 14.36$, $p < 0.001$, $\eta_p^2 = 0.14$); ($F(1,91) = 7.01$, $p = 0.01$, $\eta_p^2 = 0.07$); ($F(1,91) = 9.01$, $p = 0.003$, $\eta_p^2 = 0.09$); ($F(1,91) = 5.70$, $p = 0.02$, $\eta_p^2 = 0.06$); ($F(1,91) = 4.93$, $p = 0.03$, $\eta_p^2 = 0.05$)] respectively for the measurement minutes 0,3,6,9,12,15 and 18. The same analysis also showed significant differences between groups [($F(2,91) = 6.58$, $p = 0.002$, $\eta_p^2 = 0.13$); ($F(1,91) = 3.74$, $p = 0.03$, $\eta_p^2 = 0.08$)] respectively for the 9th and 18th minute, and no significant interaction between times and groups. Paired comparison showed significant differences between pre and post training lactate values for HIFT ($p = 0.01-0.03$, $d = 0.52-0.7$ [moderate]) and CHIC ($p = 0.009-0.03$, $d = 0.58-0.73$ [moderate]) within minutes 0; 3; 6; 9 and 12 (Figure 4). The post-hoc test showed significant differences between the lactate means of HIFT ($p = 0.04$, $d = 0.64$ [moderate]) and CHIC ($p = 0.005$, $d = 0.76$ [moderate]) when compared to RT group at 16W in the 9th minute, additionally the means of CHIC ($p = 0.04$, $d = 0.61$ [moderate]) were significantly lower than RT at 16W in the 18th minute.

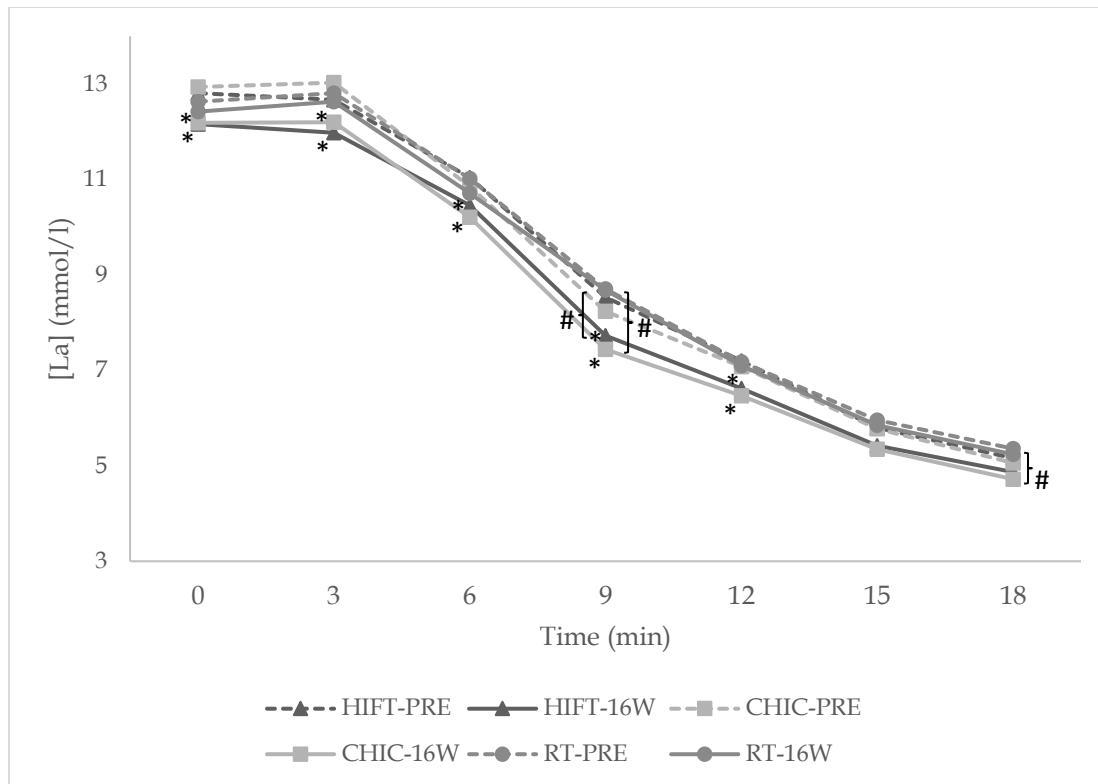
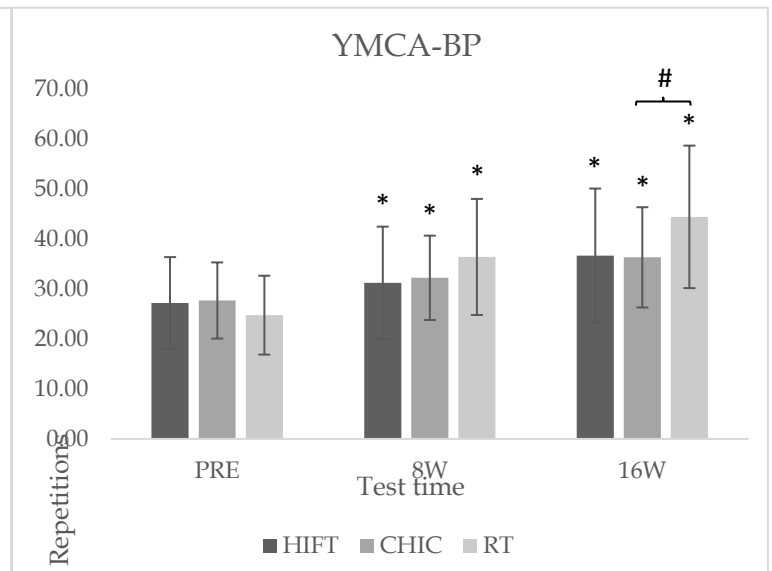
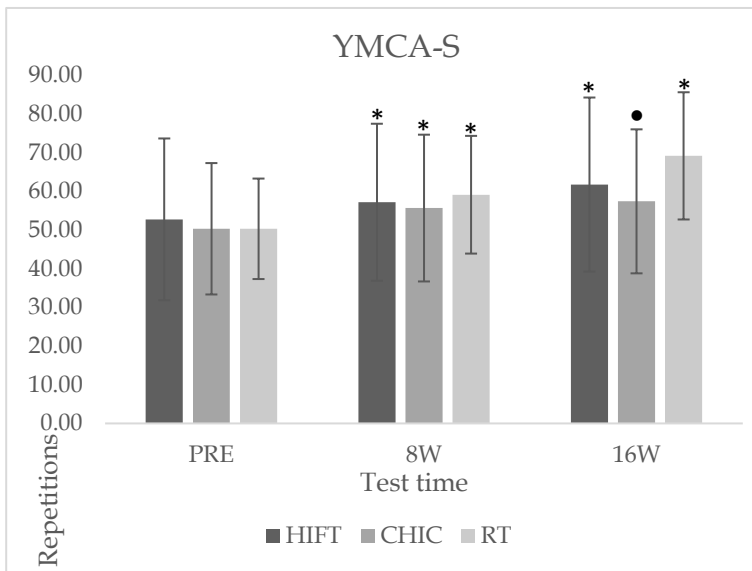
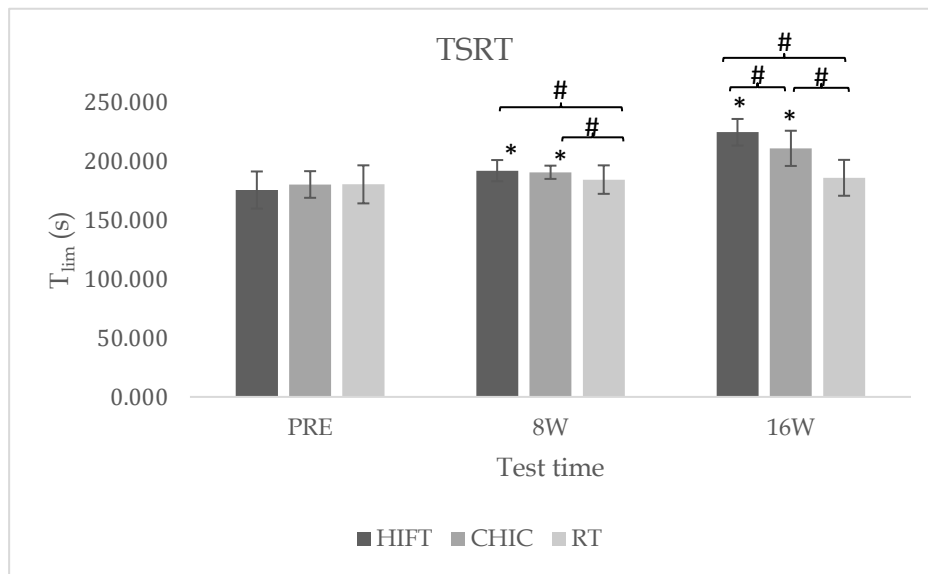


Figure 4. Blood lactate samples taken immediately after the SRT test and at the 3rd, 6th, 9th, 12th, 15th and 18th minute later. * = Significant intra-subject difference at $p < 0.05$, # = Significant inter-subject difference at $p < 0.05$, HIFT = High intensity functional training, CHIC = Choreographed high intensity classes, RT = resistance training, PRE = Pre-training, 16W = 16 weeks.

TSRT test results showed a significant time \times group interaction ($F(2,91) = 25.81, p < 0.001, \eta_p^2 = 0.36$), a significant difference between times ($F(2,91) = 123.45, p < 0.001, \eta_p^2 = 0.57$) and between groups ($F(2,91) = 27.38, p < 0.001, \eta_p^2 = 0.37$). Paired comparison showed an evolution in T_{lim} of HIFT ($p < 0.001, d = 1.28-3.19$ [large]) and CHIC ($p < 0.001, d = 1.16-1.79$ [large]) every eight weeks (Figure 5). The post-hoc test showed a significant difference of HIFT ($p = 0.005, d = 0.71$ [moderate]) and CHIC ($p = 0.03, d = 0.66$ [moderate]) compared to RT group at 8W, also a significant difference between HIFT and CHIC groups ($p = 0.001, d = 1.03$ [large]), and respectively of these last two groups compared to RT ($p < 0.001, d = 2.88$ [large]; $p < 0.001, d = 1.65$ [large]) at 16W.

The multivariate analysis of variance of muscle endurance results showed a statistically significant difference throughout different times of measurements (*Wilk's Λ* = 0.356, $F(24,160) = 4.51, p < 0.001, \eta_p^2 = 0.40$). The post-hoc test of YMCA - S results showed significant improvement in HIFT ($p = 0.001-0.002, d = 0.14$ [negligible]) and RT ($p < 0.001, d = 0.61-0.63$ [moderate]) groups every eight weeks and for CHIC after the first eight weeks ($p < 0.001, d = 0.29$ [small]) and after 16 weeks ($p < 0.001, d = 0.39$ [small]) (Figure 5), despite this development there was no significant difference between groups. YMCA - BP test results was similar to YMCA - S, showing significant improvement in all three groups; HIFT ($p < 0.001, d = 0.39-0.44$ [small]), CHIC ($p = 0.001-0.002, d = 0.44-0.56$ [small-moderate]) and RT ($p < 0.001, d = 0.61-1.17$

[moderate-large]) every eight weeks and only one difference between RT and CHIC groups ($p = 0.04$, $d = 0.65$ [moderate]) at 16W (Figure 5). YMCAM - S test results showed significant improvements only in HIFT group every eight weeks ($p = 0.008-0.02$, $d = 0.13-0.2$ [negligible]), and no significant difference between groups. YMCAM - BP test results showed significant improvement in HIFT group every eight weeks ($p = 0.01-0.03$, $d = 0.19-0.2$ [negligible]) and RT during the second eight weeks ($p = 0.03$, $d = 0.3$ [negligible]) also no significant difference between groups (Figure 5).



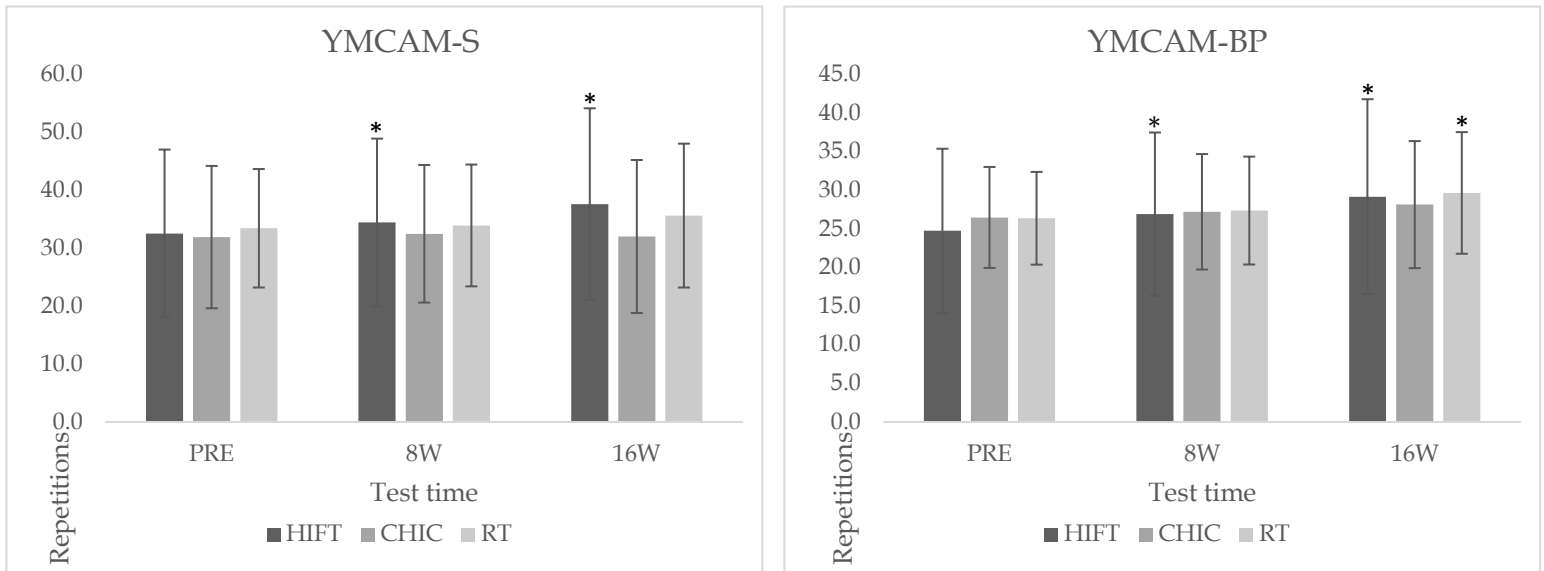


Figure 5. Histograms of the results after the different endurance tests measurements. * = Significant intra-subject difference at $p < 0.05$ compared to the previous measurement, • = Significant intra-subject difference at $p < 0.05$ compared to the first measurement, # = Significant inter-subject difference at $p < 0.05$, HIFT = High intensity functional training, CHIC = Choreographed high intensity classes, RT = resistance training, PRE = Pre-training, 8W = 8weeks, 16W = 16 weeks

The multivariate analysis of variance showed a statistically significant difference in body composition results based on time of measurements (*Wilk's Λ* = 0.095, $F(24,160) = 14.93$, $p < 0.001$, $\eta_p^2 = 0.69$). The post-hoc test showed that all 3 groups improved their body fat percentages every eight weeks: HIFT ($p < 0.001$, $d = 0.37$ – 0.53 [small]), CHIC ($p < 0.001$, $d = 0.44$ – 0.54 [small]) and RT ($p = 0.001$ – 0.003 , $d = 0.17$ [negligible]), for the inter-group effect, HIFT ($p = 0.02$, $d = 0.69$ [moderate]) and CHIC ($p = 0.008$, $d = 0.78$ [moderate]) differed significantly from RT group at 16W (Figure 6). The results of FM was similar to BF %; HIFT ($p < 0.001$, $d = 0.26$ – 0.3 [small]) and CHIC ($p < 0.001$, $d = 0.43$ – 0.53 [small]) improved every eight weeks while RT only after 16 weeks ($p = 0.03$, $d = 0.14$ [small]), the comparison between groups showed a significant difference of CHIC group compared respectively to HIFT ($p = 0.04$, $d = 0.63$ [moderate]) and RT ($p = 0.001$, $d = 0.97$ [large]) at 16W. FFM results also showed significant improvements in HIFT ($p = 0.001$ – 0.002 , $d = 0.06$ – 0.15 [negligible]) and RT groups throughout the study period ($p < 0.001$, $d = 0.17$ – 0.33 [negligible–small]), despite this improvement, the post-hoc test did not detect a significant difference between groups. The analysis of variance of the TBW results did not detect any significant change in either times ($p = 0.70$; $\eta_p^2 = 0.004$) or groups ($p = 0.81$; $\eta_p^2 = 0.005$) (Figure 6).

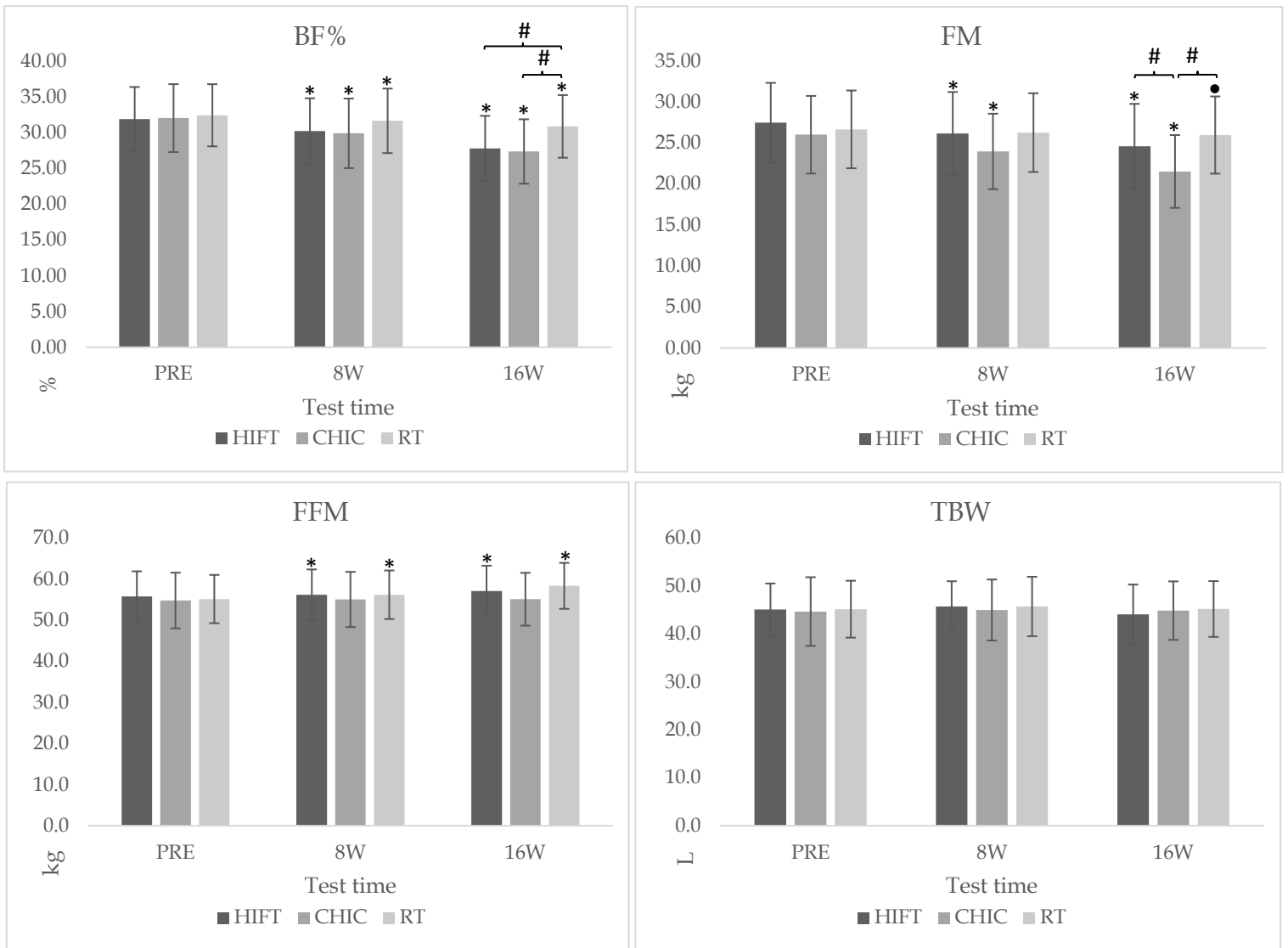


Figure 6. Representation of the body composition measurements. * = Significant intra-subject difference at $p < 0.05$ compared to the previous measurement, • = Significant intra-subject difference at $p < 0.05$ compared to the first measurement, # = Significant inter-subject difference at $p < 0.05$, HIFT = High intensity functional training, CHIC = Choreographed high intensity classes, RT = Resistance training, PRE = Pre-training, 8W = 8 weeks, 16W = 16 weeks

DISCUSSION

The purpose of this study was to compare and contrast changes, if any, in measures of Cardiovascular fitness (capacity and endurance), Muscular fitness (relative and absolute), and Body composition over 16 weeks between HIFT, CHIC and RT interventions in sedentary subjects. One of the primary findings of this study were that the HIFT and CHIC modalities demonstrated significant improvements in estimated aerobic capacity and aerobic endurance at 8W and 16W. La - clearance significantly improved over the course of intervention for HIFT

and CHIC when compared to PRE, while RT demonstrated no changes. All groups demonstrated improvements in BF% from PRE-8W and 8W-16W; however, HIFT and CHIC were significantly lower when compared to RT at 16W. Conversely, RT and HIFT were the only groups to demonstrate significant improvements in FFM by 16W. Collectively, these findings demonstrate various and differing physiological adaptations to these popular fitness programs, offering participants novel insights into which may most suitably to their needs.

It is well established that endurance exercise interventions improve aerobic capacity (16). More recently, positive changes have been observed in non-traditional, high-intensity, resistance-based exercise programs (35, 41). Murawska et al.2015 found that HIFT training performed 2 times/week for 12 weeks can elicit significant improvement in VO_{2max} (6.2 ml/min/kg) in young physically active subjects (32), while Brisebois et al.2018 observed significant improvements in VO_{2max} (1.8 ml/kg/min) after 8 weeks of HIFT training performed 3 times/week in inactive Adults (5). Though there are no current studies that have evaluate CHIC for improvements in VO_{2max} , we can extrapolate from similar HIIT study results. For instance, Wen et al.2019 summarized that, independent of protocol type, HIIT is highly effective for improving VO_{2max} in healthy, overweight/obese and athletic adults (46). In the current study, estimated maximal aerobic capacity, assessed through the SRT, significantly increased in the HIFT and CHIC groups at 8W and 16W. Over the first eight weeks HIFT showed an improvement of 3.35 ml/kg/min, while CHIC demonstrated 2.13 ml/kg/min. This trend continued the second eight weeks with the HIFT group showing an improvement of 3.81 ml/kg/min, while CHIC demonstrated 3.07 ml/kg/min. Importantly, no differences were observed between HIFT and CHIC at any time point. Though both HIFT and CHIC differ from conventional training modalities aimed to improve aerobic capacity (e.g., running and cycling), aspects of their prescription provide adequate stimuli for aerobic adaptation. The continuously elevated heart rate experienced during the exercise sessions reflect more closely to those of high-intensity endurance training than that experienced in RT (15, 41); for instance, an average HRmax of 90% or higher have been observed in our lab during various HIFT sessions (3, 21). Additionally, this level of intensity is suggestive of reaching or surpassing LA - threshold, which is a common target for aerobic training (14). A secondary rationale for the consistent 8-week improvement may be related to modality crossover to the SRT test. The explosive movements coupled with rapid changes in direction experienced in HIFT and CHIC may have provided neuromuscular carry over to the SRT, leading to improvement of economy rather than aerobic capacity alone. RT did not have an effect on maximal aerobic capacity of its practitioners at any time point, which is not uncommonly observed (33, 40).

For evaluation of aerobic endurance, the TSRT was used. The TRST is like that of the aerobic capacity test but evaluates how long the participant can maintain a cadence that is set to individuals maximal speed achieved in the SRT. This study observed significant improvements for 8W and 16W for both HIFT and CHIC. Notably, there were no differences between HIFT and CHIC at 8W, but by 16W, HIFT demonstrated a significant increase when compared to CHIC and RT. These results are reflective of the SRT scores discussed previously and are likely due to similar mechanisms discussed above. However, the TSRT results did differ at 16W between

HIFT and CHIC, with HIFT achieving a higher score. This may be due to the differences in their workout prescription. CHIC training is generally prescribed with bodyweight and a continuous 40–50 minute sessions (10). Whereas HIFT workouts differ both in the presence of weights and in its duration, with some bouts lasting as little as 3 minutes (8, 9). Continual high - intensity bouts lasting between 3 and 20 minutes may be more metabolically reflective of the TSRT than that of the longer duration bouts experienced in CHIC. Therefore, HIFT may prove more favorable for maintaining higher levels of intensity for longer durations.

The YMCA (absolute) and YMCAM (relative) protocols were used to measure muscular endurance. These protocols were divided into upper and lower body; squats (YMCA - S, YMCAM - S) and bench press (YMCA - BP, YMCAM - BP). Following the interventions, YMCA - S scores improved significantly for HIFT and RT at 8W and 16w, while CHIC only observed improvements at 8W. A key difference between the programs is the frequency and utilization of weighted squats (e.g., back squat, front squat), which HIFT and RT program regularly use (8, 22), leading to continuous and progressive overload. CHIC primarily programs bodyweight movements, which may explain the observed improvements at 8W, and diminishing returns by 16W. Interestingly, all groups observed significant improvements in the YMCA - BP at 8W and 16W. This may be in part due a greater ability to improve predominately type II muscle fibers of the upper body through phenotype shifts towards more endured fiber types (37). For relative muscular endurance the YMCAM protocols for both S and BP, which was prescribed at 40% of participant 1RM. The HIFT group was the only group to observe significant changes for both YMCAM - S and YMCAM - BP at 8W and 16W (Figure 5). Of the three modalities, HIFT generally prescribes weighted exercise at a higher volume (repetitions) and shorter rest periods (8, 9), providing proper stimuli for muscular endurance.

Upon the completion of the interventions, post exercise [La] was significantly lower in HIFT and CHIC groups, despite having performed a greater amount of work. These findings are supported by the study of Bishop et al.2008 who demonstrated a decrease in [La] values post supramaximal test after five weeks of HIIT training (e.g., CHIC training) (4). Additionally, [La] clearance was significantly higher in HIFT and CHIC groups up to 12 minutes post exercise when compared to their PRE values (Figure 4). Though similar significant [La] removal rate after high intensity training has been observed in previous studies (30, 42), [La] they differ from the current results in that [LA] levels immediately post exercise were higher after than before training. This is likely due to the differences in the exercise test being performed with a traditional graded exercise test yielding a greater physiological strain than the SRT. Though outside the scope of the study to determine the mechanisms involved in the observed [La] clearance, we will postulate on a few due to its relationship to aerobic and muscular endurance (47). High - intensity exercise is believed to increase the sarcolemmal lactate/H⁺ transport capacity through enhancing the production of monocarboxylate transporter proteins (MCT1, MCT4), thereby increasing the removal rate (36). It has also been postulated that improved blood flow and blood flow distribution enhances [La] removal rate following HIIT (17). Collectively, these mechanisms have both been seen to improve following high - intensity interventions (17,

36) that are similar to the HIFT and CHIC modalities and can explain the lack of improvement in the RT group.

Over the 16 - week intervention BF% significantly decreased at 8W and 16W for all groups. No differences observed between groups at 8W; however, HIFT and CHIC demonstrated a greater reduction when compared to RT at 16W. TBW was unchanged amongst the three groups, but each experienced a different body composition change over the intervention. For the RT group, FM was only slightly reduced at 16W, despite seeing a significant reduction in BF% at 8W and 16W. This is likely due to increased FFM observed at 8W and 16W timepoints. When evaluating HIFT, FM was significantly reduced, and FFM increased at each timepoint. Lastly, CHIC demonstrated no improvements in FFM, but did observe the highest decreases in FM by 16W. Overall, body composition changes observed in RT was predominately the result of increased FFM; HIFT composition changes were due to a combination of FFM gain and FM reduction; and CHIC composition changes were strictly the result of FM reduction. A recent review of the literature reported similar results supporting HIIT based interventions reducing BF% and FM (43), similar to the findings related to CHIC. Several studies have demonstrated improvements in body composition following HIFT, with Schlegel.2020 demonstrating BF% changes through decreasing body fat (41), while Murawska et al.2015 demonstrated significant increase in lean body mass after 3 months of HIFT training (32). The RT results are supported by Fleck et al.2014 (11) who reviewed resistance training as efficient in reducing body fat, with greater changes in body composition being observed with high - volume multiple - set programs, similar to the protocol of this study, while some studies have reported increases in FFM as high as 3 kg in over a 10 week period of resistance training (11)

Overall, the findings of this study provide a litany of physiological responses to 16 weeks of training of HIFT, CHIC, and RT. Aerobically, HIFT and CHIC were both effective in aerobic improvements. Muscular Endurance was improved in all interventions, but was most effective in HIFT group for both relative and absolute endurance. For body Composition, each program demonstrated the ability to reduce BF%. The desired manner of composition change dictates the most “efficient” training protocol, with RT providing improvements based on increased FFM; CHIC on FM reduction alone; and HIFT with a combination of the two. Each program provides some benefit in endurance and body composition; however, HIFT appears to be the most overall effective training protocol to improve endurance, and body composition.

REFERENCES

1. Amann M, Hopkins WG, Marcora SM. Similar sensitivity of time to exhaustion and time - trial time to changes in endurance. *Medicine and Science in Sports and Exercise* 40(3): 574, 2008.
2. Anderson T, Kearney JT. Effects of three resistance training programs on muscular strength and absolute and relative endurance. *Research Quarterly for Exercise and Sport* 53(1): 1 - 7, 1982.
3. Bechke E, Kliszczewicz B, Feito Y, Kelemen H, Nickerson B. Resting cardiac autonomic activity and body composition following a 16 - week high - intensity functional training intervention in women: A pilot study. *Universidad de Alicante Área de Educación Física y Deporte* 2017.

4. Bishop D, Edge J, Thomas C, Mercier J. Effects of high - intensity training on muscle lactate transporters and postexercise recovery of muscle lactate and hydrogen ions in women. *American Journal of Physiology - Regulatory, Integrative and Comparative Physiology* 295(6): R1991 - R1998, 2008.
5. Brisebois MF, Rigby BR, Nichols DL. Physiological and fitness adaptations after eight weeks of high - intensity functional training in physically inactive adults. *Sports* 6(4):146, 2018.
6. Claudino JG, Gabbett TJ, Bourgeois F, de Sá Souza H, Miranda RC, Mezêncio B, Soncin R, Cardoso Filho CA, Bottaro M, Hernandez AJ. Crossfit overview: Systematic review and meta - analysis. *Sports medicine - open* 4(1): 1 - 14, 2018.
7. Cohen J. *Statistical power analysis for the behavioral sciences*. Academic press; 2013.
8. Crossfit. Level 1 training guide. In: I Crossfit editor 2019, p 258.
9. Feito Y, Heinrich KM, Butcher SJ, Poston WSC. High - intensity functional training (hft): Definition and research implications for improved fitness. *Sports* 6(3): 76, 2018.
10. Felstead A, Bishop D, Fuller A, Jewson N, Lee T, Unwin L. Moving to the music: Learning processes, training and productive systems—the case of exercise to music instruction. *Cardiff School of Social Sciences*:43pp, 2006.
11. Fleck SJ, Kraemer W. *Designing resistance training programs*, 4e. Human Kinetics; 2014.
12. Hamdouni H, Kliszczewicz B, Zouhal H, Rhibi F, Ben Salah FZ, Ben Abderrahman A. Effect of three fitness programs on strength, speed, flexibility and muscle power on sedentary subjects. *J Sports Med Phys Fitness* 62(1): 25 - 38, 2022.
13. Harvey AL. Quantifying and comparing activity in group exercise classes - a literature review. *Journal of Fitness Research* 1(1): 50 - 65, 2012.
14. Helgerud J, Engen LC, Wisløff U, Hoff J. Aerobic endurance training improves soccer performance. *Medicine & Science in Sports & Exercise* 33(11): 1925 - 1931, 2001.
15. Hunter GR, Seelhorst D, Snyder S. Comparison of metabolic and heart rate responses to super slow vs. Traditional resistance training. *The Journal of Strength & Conditioning Research* 17(1): 76 - 81, 2003.
16. Jones AM, Carter H. The effect of endurance training on parameters of aerobic fitness. *Sports medicine* 29(6): 373 - 386, 2000.
17. Juel C, Klarskov C, Nielsen JJ, Krstrup P, Mohr M, Bangsbo J. Effect of high - intensity intermittent training on lactate and h⁺ release from human skeletal muscle. *American Journal of Physiology - Endocrinology and Metabolism* 286(2):E245 - E251, 2004.
18. Jung AP. The impact of resistance training on distance running performance. *Sports Medicine* 33(7): 539 - 552, 2003.
19. Kerksick CM, Wilborn CD, Roberts MD, Smith - Ryan A, Kleiner SM, Jäger R, Collins R, Cooke M, Davis JN, Galvan E. ISSN exercise & sports nutrition review update: Research & recommendations. *Journal of the International Society of Sports Nutrition* 15(1): 1 - 57, 2018.

20. Kim PS, MAYHEW JL, PETERSON DF. A modified ymca bench press test as a predictor of 1 repetition maximum bench press strength. *The Journal of Strength & Conditioning Research* 16(3): 440 - 445, 2002.
21. Kliszczewicz B, Feito Y, Bycura D, Brown D, Price B. Vagal response to 15 - weeks of high - intensity functional training: A pilot study. *Journal of Sport and Human Performance* 4(3)2016.
22. Kraemer WJ, Ratamess NA. Fundamentals of resistance training: Progression and exercise prescription. *Medicine & Science in Sports & Exercise* 36(4): 674 - 688, 2004.
23. Leger LA, Mercier D, Gadoury C, Lambert J. The multistage 20 metre shuttle run test for aerobic fitness. *Journal of sports sciences* 6(2): 93 - 101, 1988.
24. León - Quismondo J, García - Unanue J, Burillo P. Best practices for fitness center business sustainability: A qualitative vision. *Sustainability* 12(12): 5067, 2020.
25. León - Quismondo J, García - Unanue J, Burillo P. Service perceptions in fitness centers: Ipa approach by gender and age. *International journal of environmental research and public health* 17(8) 2020.
26. Mangrané A. Training art, tracking discourse. Novia University of Applied Sciences; 2020.
27. Matsuzaka A, Takahashi Y, Yamazoe M, Kumakura N, Ikeda A, Wilk B, Bar - Or O. Validity of the multistage 20 - m shuttle - run test for japanese children, adolescents, and adults. *Pediatric Exercise Science* 16(2): 113 - 125, 2004.
28. Menezes Júnior FJd, Jesus ÍCd, Leite N. Predictive equations of maximum oxygen consumption by shuttle run test in children and adolescents: A systematic review. *Revista Paulista de Pediatria* 37(2): 241 - 251, 2019.
29. Mialich MS, Sicchieri JMF, Junior AAJ. Analysis of body composition: A critical review of the use of bioelectrical impedance analysis. *International Journal of Clinical Nutrition* 2(1): 1 - 10, 2014.
30. Mohr M, Krstrup P, Nielsen JJ, Nybo L, Rasmussen MK, Juel C, Bangsbo J. Effect of two different intense training regimens on skeletal muscle ion transport proteins and fatigue development. *American Journal of Physiology - Regulatory, Integrative and Comparative Physiology* 292(4): R1594 - R1602, 2007.
31. Mosley PE. Bigorexia: Bodybuilding and muscle dysmorphia. *European Eating Disorders Review: The Professional Journal of the Eating Disorders Association* 17(3): 191 - 198, 2009.
32. Murawska - Cialowicz E, Wojna J, Zuwała - Jagiello J. Crossfit training changes brain - derived neurotrophic factor and irisin levels at rest, after wingate and progressive tests, and improves aerobic capacity and body composition of young physically active men and women. *Journal of Physiology and Pharmacology* 66(6): 811 - 821, 2015.
33. Murlasits Z, Kneffel Z, Thalib L. The physiological effects of concurrent strength and endurance training sequence: A systematic review and meta - analysis. *Journal of sports sciences* 36(11): 1212 - 1219, 2018.
34. Navalta JW, Stone WJ, Lyons TS. Ethical issues relating to scientific discovery in exercise science. *International journal of exercise science* 12(1): 1, 2019.
35. Oliver - López A, García - Valverde A, Sabido R. Summary of the evidence on responses and adaptations derived from crossfit training. A systematic review. *Retos* 46: 309 - 322, 2022.

36. Pilegaard H, Domino K, Noland T, Juel C, Hellsten Y, Halestrap AP, Bangsbo J. Effect of high - intensity exercise training on lactate/h⁺ transport capacity in human skeletal muscle. *American Journal of Physiology - Endocrinology and Metabolism* 276(2): E255 - E261, 1999.
37. Plotkin DL, Roberts MD, Haun CT, Schoenfeld BJ. Muscle fiber type transitions with exercise training: Shifting perspectives. *Sports* 9(9): 127, 2021.
38. Riebe D, Ehrman JK, Liguori G, Magal M, Medicine ACoS. *Acsm's guidelines for exercise testing and prescription*. Wolters Kluwer; 2018.
39. Riseth L, Nost TH, Nilsen TI, Steinsbekk A. Long - term members' use of fitness centers: A qualitative study. *BMC sports science, medicine and rehabilitation* 11:2, 2019.
40. Sabag A, Najafi A, Michael S, Esgin T, Halaki M, Hackett D. The compatibility of concurrent high intensity interval training and resistance training for muscular strength and hypertrophy: A systematic review and meta - analysis. *Journal of sports sciences* 36(21): 2472 - 2483, 2018.
41. Schlegel P. Crossfit® training strategies from the perspective of concurrent training: A systematic review. *Journal of sports science & medicine* 19(4): 670, 2020.
42. Sharp R, Costill D, Fink W, King D. Effects of eight weeks of bicycle ergometer sprint training on human muscle buffer capacity. *International journal of sports medicine* 7(1): 13 - 17, 1986.
43. Sultana RN, Sabag A, Keating SE, Johnson NA. The effect of low - volume high - intensity interval training on body composition and cardiorespiratory fitness: A systematic review and meta - analysis. *Sports Medicine* 49(11): 1687 - 1721, 2019.
44. Thompson WR. Worldwide survey of fitness trends for 2020. *ACSM'S Health & Fitness Journal* 23(6): 10 - 18, 2019.
45. Thompson WR. Worldwide survey of fitness trends for 2022. *ACSM's Health & Fitness Journal* 26(1): 11 - 20, 2022.
46. Wen D, Utesch T, Wu J, Robertson S, Liu J, Hu G, Chen H. Effects of different protocols of high intensity interval training for vo₂max improvements in adults: A meta - analysis of randomised controlled trials. *Journal of science and medicine in sport* 22(8): 941 - 947, 2019.
47. Yoshida T, Chida M, Ichioka M, Suda Y. Blood lactate parameters related to aerobic capacity and endurance performance. *European journal of applied physiology and occupational physiology* 56(1): 7 - 11, 1987.

