Original Article

Physiological comparison between competitive and beginner high intensity functional training athletes

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ABSTRACT

Introduction: Among high intensity trainings, high intensity functional training (HIFT) represent one of the most recent developments. The aim of the present study was to investigate the differences between a group of competitive (CMP) HIFT athletes and a group of age- and gender-matched beginner (BGN) HIFT athletes, to clarify the physiological characteristics of each group and the reasons for differences. Methods: 10 BGN (32.5 ± 6.2 years) and 10 CMP (29.0 ± 5.4 years) athletes, were included in the study and were evaluated for anthropometry, VO_{2peak}, lactate threshold, isometric and isokinetic leg maximal power and strength, handgrip and maximal anaerobic power. Results: Compared to BGN athletes, CMP reached higher levels of VO_{2peak} (56.1 ± 2.89 ml·kg^{-1}·min^{-1} CMP vs. 46.5 ± 6.86 ml·kg^{-1}·min^{-1} BGN; $p < .001$), lower limb maximal power (4.5 ± 0.42 W·kg^{-1} CMP vs. 2.9 ± 0.67 W·kg^{-1} BGN; $p < .001$), maximal handgrip strength (61.1 ± 8.20 N·kg^{-1} CMP vs. 45.1 ± 7.58 N·kg^{-1} BGN; $p < .001$), maximal knee extension isometric strength (11.7 ± 1.43 N·kg^{-1} CMP vs. 9.1 ± 2.00 N·kg^{-1} BGN; $p < .05$), isokinetic strength (281.3 ± 28.18 N·kg^{-1} CMP vs. 234.6 ± 26.15 N·kg^{-1} BGN; $p < .05$) and anaerobic peak power (639.1 ± 125.54 W·kg^{-1} CMP vs. 442.7 ± 155.96 W·kg^{-1} BGN; $p > .006$), while anaerobic capacity did not show significant differences (101.8 ± 9.33 kJ CMP vs. 87.0 ± 28.37 kJ BGN; $p = .1$). Conclusions: CMP athletes showed greater physiological adaptations in aerobic fitness and strength than BGN. Differences may be attributed to the technical skills acquired by CMP and not only to the physiological adaptations induced by the specific training. The lack of differences in anaerobic capacity is likely due to an early and fast improvement in BGN, compared to other parameters.

Keywords: Physical fitness; CrossFit; High intensity functional training; General preparedness programs; Functional exercise.

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INTRODUCTION

Within the large family of high intensity trainings, high intensity functional training (HIFT) represent one of the most recent and successful developments. In order to ensure consistency among high intensity training modalities, HIFT has been defined by Feito et al., as “a training style (or program) that incorporates a variety of functional movements, performed at high intensity (relative to an individual’s ability), designed to improve parameters of general physical fitness (cardiovascular endurance, strength, body composition, flexibility, etc.) and performance (agility, power, speed, and strength)” (Feito, Heinrich, Butcher, & Poston, 2018).

The unique feature of HIFT programmes is the incorporation of various exercise modalities into the same training session, including Olympic weightlifting (e.g. barbell squats, snatch) bodyweight calisthenics (e.g. push-ups, burpees), gymnastics movements (e.g. handstand, ring exercises) and cardiovascular activities (e.g. running, indoor rowing), with the focus on improving the capacity to perform large amounts of work during relatively short training sessions. Thanks to its characteristics and comprehensiveness, HIFT challenges multiple systems in a single session, therefore athletes show physiological features that are key to many different sports. This represents one of the most attractive reasons to start HIFT programmes, making them particularly suitable for individuals interested in general preparedness programs or multi-sport athletes. HIFT are often adopted also by sedentary or relatively physically active individuals, thanks to the self-selected intensity levels that participants can establish each time. This aspect dramatically increases adherence and enjoyment (Heinrich, Patel, O'Neal, & Heinrich, 2014). In all cases it is strongly recommended to progressively increase the physical activity levels before approaching high intensities and HIFT regimes, to avoid injuries and maladaptive conditions (Bergeron et al., 2011).

Although it may be obvious that experienced athletes have higher physiological characteristics than beginner athletes, the extent of these differences is still yet to be determined in the context of HIFT. Whether these might be accountable to physiological adaptations, proper technical skill development, previous physical activity levels, or a combination of all, must be demonstrated. It remains also to be established if, in the context of an HIFT program, all the physical fitness components would improve and respond at the same time to the training stimulus, or some might be improving faster than others.

Albeit information on the physiological characteristics of competitive HIFT athletes have been previously published (P.E. Adami, Rocchi, Melke, & Macaluso, 2020; Serafini et al., 2016), the short term effect of HIFT programmes on beginner participants still needs to be clarified.

Therefore, the aim of the present study was to investigate the differences between a group of competitive HIFT athletes and a group of age- and gender-matched beginner HIFT athletes in order to clarify the physiological characteristics of each group and the reasons for such differences. It was hypothesised, therefore, that competitive athletes would have shown training induced physiological adaptations of a greater magnitude with respect to beginners.

METHODS

Study population

A group of 20 male HIFT athletes, 10 competitive (CMP) and 10 beginner (BGN) athletes, were included in the study. The BGN group of athletes practiced HIFT for less than 12 weeks (a minimum of 3 training session of at least 60 minutes each, every week), while CMP athletes have been practicing HIFT for at least 3 years (a minimum of 4 training session of at least 55 minutes each, every week) and competed at national level for a minimum of 1 year. All subjects were evaluated by a sports physician prior to their enrolment in the study, to confirm their health status and absence of cardiovascular risks. Written informed consent was obtained from each athlete undergoing the evaluation, compliant with Italian law and the University policies. The study design was approved by the Review Board of the University of Rome "Foro Italico" (CAR 13/2019). All clinical data assembled from athletes are maintained in a secured institutional database, compliant with GDPR regulations.

Subjects enrolled in the study, reported to the laboratory of exercise physiology on two separate days. On the first day (T1), selected athletes were informed of the purpose, risks, and objectives of the study. Athletes had their body composition and anthropometric parameters measured. They were then tested for VO_{2max} and ventilatory threshold, maximal anaerobic alactic capacity, handgrip, maximal isometric strength in leg extension and leg flexion, isokinetic leg extension and leg flexion strength in dynamic conditions. Participants returned to the laboratory on a second occasion (T2) to complete a running based anaerobic sprint test (RAST) on an outdoor football pitch. Before coming to the testing laboratory, participants were instructed to restrain from exercise for the previous 12 hours, avoid alcohol consumption for at least 24 hours and avoid consuming food or beverages, other than water, for four hours prior to being tested. All indoor tests were performed wearing light and comfortable clothing (e.g. shorts and t-shirt) as desired by the athlete, and in a standardized environment (e.g., temperature and humidity changes).

Anthropometric evaluation
Body composition assessment was performed through skin-fold plicometry at seven sites, according to Jackson and Pollock (Jackson & Pollock, 1978), always by the same experienced researcher. Anthropometric parameters were also recorded (stature and body mass) and body surface area (BSA) was then calculated.

Maximal oxygen consumption
All subjects underwent a cardiopulmonary exercise test to measure their VO_{2max} and ventilatory threshold. The test consisted of a ramp incremental maximal exercise test on a treadmill, with a test protocol that has been previously described and validated in this type of athletes (Bellar, Hatchett, Judge, Breaux, & Marcus, 2015). An initial stage of 30-second at 5.6 kilometres per hour, to allow subjects to familiarize with the device, was followed by a two-minute warm up stage at 5.6 kilometres per hour and a 2.0% grade inclination. After the warm up stage, speed and grade were increased every 2 minutes by 1.6 kilometres per hour and 1.5% respectively, until the conclusion of the test. The test aimed at reaching individuals' exhaustion and this was considered reached when the athlete was unable to maintain the pace despite constant encouragement, or when at least two of the following criteria were attained during the exercise phase of the test ("Clinical Exercise Testing," 2012):

a) A heart rate equivalent to 100% of the age predicted maximum (220 – age, years);
b) Levelling off or decline in the VO_2 with increasing work rate;
c) A respiratory exchange ratio ≥ 1.10.

The exercise phase was followed by a passive recovery phase, in standing position, with continuous metabolic monitoring lasting for at least 5 minutes. Each subject was fitted with a heart rate (HR) monitor (Polar, Finland), and with a face mask connected to a portable metabolimeter (K4b2, COSMED, Italy). Oxygen uptake (VO_2) and carbon dioxide production (VCO_2) were measured breath-by-breath. HR signal was transmitted and recorded by the portable system. The system was calibrated prior to each test according to the manufacturer's specifications. Every two minutes and up until exhaustion, investigators invited participants to estimate their perceived exertion on a printed Borg 6-20 Rate of Perceived Exertion (RPE) scale (Borg, 1998). The anaerobic threshold (AT) was established with a double-blind comparison between the V-slope method (i.e. the V-slope method involves the analysis of the behaviour of VCO_2 as a function of VO_2 and assumes that the threshold corresponds to the break in the linear VCO_2-VO_2 relationship) (Beaver, Wasserman, & Whipp, 1986) and the ventilator equivalent method (i.e. a systematic increase in the ventilatory equivalent of O_2 [VE/VO_2], with no concomitant rise in the ventilatory equivalent of CO_2 [VE/VCO_2]) (Wasserman, Whipp, Koyl, & Beaver, 1973).

Lower limbs maximal power

Athletes' maximal anaerobic alactic capacity was measured through a standardized two-legs squat jump (SJ) performed on a force platform (model 9281 B; KISTLER Instrumente GmbH, Sindelfingen, Germany). Vertical jump has been widely used to measure lower extremity power and to track performance improvements in many sports. (Bui, Farinas, Fortin, Comtois, & Leone, 2015) The assessment was performed, in order to look at the relationship between muscle power and functional capacity (Macaluso & De Vito, 2004). Each participant performed three jumps interspersed by a 1-min rest. Squat jumps were started from a static standing position. Subjects were instructed to perform a countermovement to reach the squat position before jumping as high and explosively as possible. The depth of the countermovement was determined instinctively by the athletes themselves and supervised visually by an investigator to ensure consistency in individuals' jump execution, as it has been previously described (Gross & Lüthy, 2020; Labanca et al., 2016; Macaluso, Young, Gibb, Rowe, & De Vito, 2003). Maximal power output, optimal speed and optimal force were then calculated as described in the literature (P.E. Adami et al., 2020). The maximal instantaneous peak power was reported in watts per kilogram of body mass.

Handgrip maximal voluntary isometric strength

Handgrip strength was measured by means of a dynamometer (Baseline®, Hydraulic Hand Dynamometer, Fabrication Enterprises Inc., White Plains, NY, 10602, USA). Handgrip measurements were performed three times per hand, alternating hands, with 1-min recovery between each measurement. Before starting the test, participants were instructed to exert their maximum strength and keep the grip for at least 5 seconds, as described in the literature (Mathiowetz et al., 1985). The maximum handgrip strength of each hand was measured in kilograms (kg) and only the average values of the three trials per hand, were included in the analysis.

Leg extension and leg flexion maximal voluntary isometric strength

The maximal strengths produced through a voluntary isometric contraction during leg extension and leg flexion were measured for both legs. According to protocols already validated (Menotti et al., 2012), participants were seated in a leg-extension and leg-curl machines (Technogym Selection, Technogym, Forlì-Cesena, Italy), with 90° of flexion at the hip and knee joints. The device's rigid leg cuff was linked to a strain-gauge load cell by means of a stiff steel rod (Muscle Lab Force Sensor, Ergotest technology AS, Porsgrunn, Norway). On a given signal from the investigator, subjects were instructed to execute the leg-extension and leg-flexion movements as fast and explosively as possible (Bemben, Clasey, & Massey, 1990). The peak isometric torque (N·m) exerted during the entire contraction phase represented the maximal voluntary contraction (MVC). MVC measurements were averaged for each leg from three repetitions, that were executed with 1-min recovery between each repetition.

Isokinetic leg extension and leg flexion strength

Isokinetic leg extension and leg flexion strength were measured with an Easytech Genu 3 isokinetic dynamometer (Easytech srl, Borgo San Lorenzo, FI, Italy). The test consisted of two trials of knee extensions and flexions for each leg, executed at two different angular speeds, i.e. 90°·s-1 and 180°·s-1. The first trial consisted of 4 contractions at 90°·s-1 speed, with the objective of measuring maximal strength capacity both in extension and flexion. The second trial, consisted of 20 contractions at 180°·s-1 speed, aimed at assessing the muscular power (work) and the fatigue index (power decrease), as described in the literature (Stumbo et al., 2001). Before starting the test, participants were optimally positioned on the Easytech chair with stabilization straps at the trunk, hips and thigh, while holding with their hands to handles. The knee joint rotation axis coincided with the rotation axis of the dynamometer. Prior to each test, the dynamometer was calibrated following the manufacturer instructions.

Running-based Anaerobic Sprint Test

A running based anaerobic sprint test (RAST) was used to assess the maximal anaerobic lactic power (Zacharogiannis, Paradisis, & Tziortzis, 2004). As an adapted running version of the Wingate test, RAST is able to provide anaerobic capacity (AnC), peak power (PP), mean power (MP), relative peak power (RPP) and fatigue index (FI) data, that correspond to the Wingate mechanical power produced by the recruited muscular group (Queiroga et al., 2013). To determine the lactate peak concentrations ([LAC]PEAK), a 5 ml sample of capillary blood was taken from the ear lobe and peripheral blood lactate concentration was measured using a Lactate Pro 2 analyser (KDK Array, Japan), before starting the test and at 1', 3', 5', 7' post-test (Wasserman, Beaver, & Whipp, 1986).

Statistical analysis

The study was designed as a prospective cohort study of the physical features of two groups of HIFT athletes, recruited from several training centres in the city of Rome, Italy. Descriptive statistics were performed using means ± SD. Normality of the distributions was assessed by means of the Shapiro-Wilk test. Comparison between groups was carried out using ANOVA for independent samples. Cohen's d was also calculated for assessing the effect size (ES). Simple Pearson's r correlations were used to determine the associations between tests performance data. Countermovement jump analysis of maximal power, optimal velocity and optimal force was performed using a custom Matlab programme (Mathworks, Inc., Natick, MA, USA). Statistical analysis was performed using SPSS (version 22, SPSS Inc. Chicago IL, USA) and statistical significance was set at $p < .05$.

RESULTS

Anthropometric data

Populations' anthropometric characteristics are presented in Table 1. Athletes' age was 29.0 ± 5.4 (18–36) years in CMP and 32.5 ± 6.2 (19–39) in BGN athletes. Mean measures of body mass, height and body surface area (BSA) were significantly greater for CMP than BGN. CMP had also a higher lean body mass (LBM) and less body fat than BGN athletes. Nevertheless, both groups showed body fat percentage that can be considered in the optimal range, based on gender, age and ethnicity criteria (Gallagher et al., 2000; Kelly, Wilson, & Heymsfield, 2009; Rodriguez, DiMarco, & Langley, 2009). In CMP and in BGN athletes, lean body mass correlated positively with dominant handgrip strength ($p < .05$, $r = 0.71$ in elite and $p < .05$, $r = 0.76$ in amateur). Training time showed significant differences between the two groups. CMP athletes trained on average 373.6 ± 119.31 minutes per week, while BGN athletes trained on average 239.7 ± 59.90 minutes per week ($p < .05$).

Maximal oxygen consumption

VO_{2peak} absolute and normalized for body mass values were significantly greater in CMP athletes than in BGN. Both groups reached similar percentage of the HRmax and no differences were present in terms of Lactate Threshold % of VO_{2peak}. A correlation analysis between the maximal aerobic fitness tests and other tests showed no significant correlation. Main values from the maximal incremental exercise test are presented in Table 2 and full results are available in the supplementary files.

Table 1. Anthropometric characteristics. BSA, body surface area.

	Elite	Amateur	p-value
Age (years)	29 ± 5.4	32 ± 6.2	.1
Height (m)	1.79 ± 0.043	1.74 ± 0.059	.01
Body mass (kg)	83.4 ± 6.95	71.3 ± 7.14	.002
Fat Body Mass (kg)	10.6 ± 2.31	12.5 ± 4.67	.09
Fat Body Mass (%)	12.6 ± 2.43	17.4 ± 6.00	.01
Lean Body Mass (kg)	72.8 ± 5.75	58.6 ± 5.65	<.001
BSA (m^2)	2.04 ± 0.104	1.85 ± 0.112	.002
Training volume (minutes·week)	373.6 ± 119.31	239.7 ± 59.90	.03

Table 2. Values of major variables from all test.

Variables	Competitive	Beginners	p-value
Maximal oxygen consumption			
VO_{2peak}/kg (ml·kg^{-1}·min^{-1})	56.1 ± 2.89	46.5 ± 6.86	<.001
VO_2@LT % of VO_{2peak}	79.7 ± 10.85	80.2 ± 4.25	.8
Squat Jump			
Maximal power (W·kg^{-1})	4.5 ± 0.42	2.9 ± 0.67	<.001
Optimal speed (ms^{-1}·kg^{-1})	2.8 ± 0.15	2.2 ± 0.24	<.001
Optimal force (N·kg^{-1})	2.1 ± 0.28	1.2 ± 0.18	<.001
Handgrip			
Maximal strength (N·kg^{-1})	61.1 ± 8.20	45.1 ± 7.58	<.001
Maximal voluntary isometric strength			
Peak torque extension (N·kg^{-1})	11.7 ± 1.43	9.1 ± 2.00	.004
Peak torque flexion (N·kg^{-1})	7.4 ± 1.18	7.5 ± 1.94	.9
Isokinetic strength			
Maximal torque momentum extension (N·kg^{-1})	281.3 ± 28.18	234.6 ± 26.15	.001
Maximal torque momentum flexion (N·kg^{-1})	173.3 ± 31.45	126.3 ± 24.82	.002
Running-based Anaerobic Sprint Test			
Peak Power (W·kg^{-1})	639.1 ± 125.54	442.7 ± 155.96	.006
Anaerobic Capacity (kJ)	101.8 ± 9.33	87.0 ± 28.37	.1

Lower limbs maximal power

CMP athletes reached greater values for maximal power output, optimal speed reached, and optimal force produced compared to BGN. Maximal power and optimal force values normalized values for body mass and lean body mass were significantly greater in CMP than in BGN athletes as shown in Table 2. In CMP athletes, optimal force values positively correlated with dominant handgrip strength ($p < .05$, $r = 0.79$).

Handgrip maximal voluntary isometric strength

Handgrip strength differences were statistically significant, for both dominant and non-dominant hand, between CMP and BGN. Dominant hand strength results of CMP athletes were positively correlated with lower limb maximal power at the RAST ($p < .05$, $r = 0.82$), with optimal force at the squat jump test ($p < .05$, $r = 0.79$), with strength ($p < .05$, $r = 0.87$), maximal power ($p < .05$, $r = 0.84$) and total work ($p < .05$, $r = 0.88$) in the dominant limb in extension at the isokinetic test. Results from the dominant upper limb are shown in Table 2 while non-dominant upper limb results are presented in the supplemental material.

Table 3. Results from the maximal oxygen consumption test.

	BGN	CMP	p-value
VO_{2peak} ($ml \cdot min^{-1}$)	3256.7 ± 392.68	4413.7 ± 534.89	<.05
HR_{peak} % of HR_{max}	95.0 ± 3.89	94.9 ± 4.69	.9
VO_2@LT/kg ($ml \cdot kg^{-1} \cdot min^{-1}$)	39.2 ± 6.75	42.3 ± 7.63	.3
RPE	18.3 ± 0.82	17.9 ± 1.66	.5

HR, heart rate; RPE, rate of perceived exertion.

Table 4. Results from the Running-based Anaerobic Sprint Test (RAST).

	BGN	CMP	p-value
Fatigue Index (%)	3.8 ± 1.88	4.7 ± 2.64	.3
Total Time (s)	37.9 ± 6.07	35.8 ± 3.28	.2
Relative Peak Power	6.7 ± 2.68	6.9 ± 1.80	.4
Mean Time Per Run (s)	6.3 ± 1.01	5.9 ± 0.54	.2
$[LAC]_{PEAK}$ ($mmol \cdot L^{-1}$)	11.8 ± 4.20	9.1 ± 3.00	<.05

Table 5. Results from the isokinetic lower limb strength tests. p-values are referred to right and left legs comparison between BGN and CMP.

	BGN		CMP		p-value	p-value
4 reps 90°·s-1	**Right leg**	**Left leg**	**Right Leg**	**Left leg**	**R**	**L**
Force Ext ($N \cdot kg^{-1}$)	234.6 ± 26.15	221.1 ± 34.66	281.3 ± 28.18	269.0 ± 31.42	.001	.005
Force Flex ($N \cdot kg^{-1}$)	126.3 ± 24.82	119.9 ± 20.85	173.3 ± 31.45	162.8 ± 36.68	.002	.005
Power Max Ext (W)	325.0 ± 42.11	316.3 ± 62.24	481.0 ± 73.41	467.1 ± 75.86	<.001	<.001
Power Max Flex (W)	154.3 ± 36.52	152.4 ± 40.69	306.8 ± 68.39	283.4 ± 70.02	<.001	<.001
Total Work Ext (J)	658.8 ± 63.19	610.0 ± 109.55	814.2 ± 136.47	733.7 ± 148.58	<.004	<.04
Total Work Flex (J)	359.3 ± 57.71	332.1 ± 57.76	507.2 ± 149.02	491.8 ± 162.78	<.009	<.009
20 reps 180°·s-1	**Right leg**	**Left leg**	**Right Leg**	**Left leg**	**R**	**L**
Force Ext ($N \cdot kg^{-1}$)	177.5 ± 16.97	152.9 ± 29.65	203.6 ± 34.37	189.3 ± 29.89	.04	.01
Force Flex ($N \cdot kg^{-1}$)	96.4 ± 16.34	86.0 ± 13.63	149.3 ± 29.97	133.3 ± 23.60	<.001	<.001
Power Max Ext (W)	387.9 ± 70.74	446.8 ± 95.73	629.9 ± 111.80	609.3 ± 133.25	<.001	.006
Power Max Flex (W)	217.9 ± 22.24	212.3 ± 66.32	555.6 ± 173.56	451.7 ± 86.73	<.001	<.001
Total Work Ext (J)	2379.5±327.46	2224.0±379.32	2884.6±637.46	2892.6±635.96	.03	.01
Total Work Flex (J)	1119.4±189.04	1019.9±262.76	2101.0±669.48	1893.6±452.02	<.001	<.001

Reps, repetitions; Ext, extension; Flex, flexion.

Leg extension and leg flexion maximal voluntary isometric strength

Differences between CMP and BGN were significant for both legs in extension, with CMP showing greater peak torque values than BGN athletes. Differences were not significant in flexion. FLEX/EXT ratio showed a significant difference between CMP and BGN, with CMP athletes showing a lower strength ratio between flexor and extensor muscles (63% in CMP vs. 85% in BGN, $p < .05$). Peak torque results for the dominant leg are presented in Table 2, while the full set of results for the non-dominant leg knee-extension and knee-flexion are available in the supplemental material.

Isokinetic leg extension and leg flexion strength

Force normalized per body mass, maximal power and total work were significantly higher in CMP athletes than BGN, in extension and flexion, at both the 4 repetitions 90°·s-1 test and 20 repetitions 180°·sec-1 test. The maximal torque momentum in extension and flexion are presented in Table 2, while the full set of data for the 2 tests is available in the supplemental material.

Running-based Anaerobic Sprint Test

The PP results from the RAST are presented as values relative to kg of body mass (W·kg-1). PP, MP and top speed values were significantly higher in CMP athletes compared to BGN. FI, RPP and AnC did not show significant differences between the two groups. Interestingly in CMP athletes, average power produced during RAST, positively correlated with optimal force at the squat jump test ($p < .05$, $r = 0.81$), with dominant handgrip strength ($p < .05$, $r = 0.79$), with lower limb strength ($p < .05$, $r = 0.85$) and maximal instant power ($p < .05$, $r = 0.79$) in the dominant leg in extension at the isokinetic test. The peak power and anaerobic capacity results are shown in Table 2, while the full set of data is available in the supplemental material.

DISCUSSION

To our knowledge, this is the first study to investigate the anthropometric and physiological differences existing between a group of competitive HIFT athletes and a group of age- and gender-matched beginner HIFT athletes, through a comprehensive series of tests that includes maximal oxygen consumption, strength and anaerobic capacity. The main findings suggest an overall difference between CMP and BGN athletes, with CMP displaying greater aerobic fitness and strength performance than BGN. Although this result is not surprising and is routinely observed in other sports (Ahtiainen, Pakarinen, Alen, Kraemer, & Häkkinen, 2003; Demirkan, Koz, Kutlu, & Favre, 2015; le Gall, Carling, Williams, & Reilly, 2010; Woods, McKeown, Haff, & Robertson, 2016), further considerations should be given to explain the underlying factors for strength, aerobic fitness and anaerobic capacity.

BGN athletes have generally less experience than elites' in executing specific exercises and movements, which has an impact on strength production. Although we were not able to measure and study the technical skill level of all athletes, BGN are generally less used to generate high forces and power output during laboratory test, and less familiar with the testing environment. In particular, skill mastery and physiological adaptations result from high levels of continuous and specific practice over a considerable amount of time, with the objective of improving performance (Ericsson, 2007). These factors might help explaining the differences in results found within the BGN athletes' group itself. Acute strength adaptations are common among sedentary individuals beginning a new exercise due to neural adaptations (e.g. synchronization and recruitment of additional motor units, increased neural drive, etc.). However, these adaptations are less noticeable in those individuals who are already physically active or have been in the past. It is important to note that although BGN participants of the current study, before starting the HIFT training, were all physically active, their experience and technique associated with the execution of specific movements were limited and, therefore, might have influenced their capacity to generate high forces and produce high power output. Furthermore, the existing differences in anthropometry and body composition should also be considered when interpreting the results as these have also played a role in producing the final effect, as previously suggested (Keogh, Hume, Pearson, & Mellow, 2009).

Although the main objective of HIFT is not to specifically improve aerobic fitness, CMP athletes demonstrated high levels of maximal oxygen consumption. Several studies have demonstrated a resulting increase in oxygen consumption following high intensity trainings (Gibala & McGee, 2008; Helgerud et al., 2007; Tabata et al., 1996). Although beyond the scope of this article, the mechanisms regulating these adaptations have yet to be fully understood, but demonstrated to reach a similar extent to traditional endurance training, in a shorter time and with lower total training volume (Burgomaster et al., 2008). The commonly observed beneficial changes in resting blood pressure are mainly due to an increase in peripheral artery compliance and endothelial function of trained muscles (Rakobowchuk et al., 2008). This results in the improved delivery of O_2 to the tissues and subsequently improved a-VO_2 difference (Gibala, Little, Macdonald, & Hawley, 2012).

Cardiac central adaptation like left ventricle (LV) remodelling also has been described but it appears to require a longer training duration and greater exercise volume than that required to improve the cardiorespiratory fitness or peripheral vascular structure and function (Wisloff et al., 2007). The HIFT session structure can help explain this effect. The intense burst of exercise induces great increases in cellular and peripheral vascular stress, while the heart does not seem to be affected by those stresses, due to the brief duration of exercise bouts. This relative central "insulation" allows individuals to train at much higher intensities than they would otherwise and results in different timing in the adaptations between central and peripheral levels (Wisloff et al., 2007). An important distinction to make between general high intensity training and HIFT is the modality of the exercise used. High intensity trainings typically adopt unimodal protocols (e.g. rowing, running, cycling, arm-cranking) (P. E. Adami et al., 2015), while HIFT are multimodal, incorporating aerobic, anaerobic and resistance-based exercise all in the same workout. Most of the HIFT exercises are multi-joint movements, involving large segments of the body and prompting complex motor recruitment patterns, on multiple planes (Heinrich et al., 2014). The reason why it is important to highlight this factor is because of the pressor reflex, which was demonstrated to rapidly elevate the HR and place more stress on hemodynamics, thus representing a potential mechanism for adaptation (Collins, Cureton, Hill, & Ray, 1991). When interpreting the present study's results, it is likely that BGN athletes did not have enough training time (weeks) to develop significant central adaptations that would allow them to further increase their maximal aerobic capacity.

Participants in the study were also evaluated from an anaerobic standpoint. Although CMP athletes showed higher values of average and maximal power at the running-based anaerobic test, as expected, anaerobic capacity (AnC) values were not significantly different between CMP and BGN athletes. These results support the concept that improvements in anaerobic performance can occur following a short period of training. Indeed, it confirms that participation in high intensity programmes, results in anaerobic improvements (i.e. peak power and mean power) (Gibala & McGee, 2008; Jabbour, Iancu, & Paulin, 2015). A study conducted by Gibala et al., has demonstrated the efficacy of a two-week sprint interval training program in physically active participants in improving the anaerobic performance, which was hypothesized to happen because of the improved cellular buffering systems (Gibala et al., 2006). Albeit beginner athletes, before starting their training with high intensity functional programmes, were physically active, they were not regularly engaged in high intensity exercises, therefore, they were more likely to respond to the HIFT through the principle of anaerobic overload. Thus, it is possible that these "physically active subjects" behaved similarly to sedentary individuals, with regards to the anaerobic training effect. The general hypothesis regarding adaptation to the anaerobic overload is related to the improvements in the muscle buffering capacity, improved muscle quality and glycogen content (Gibala et al., 2012; Gibala et al., 2006; Jabbour et al., 2015).

Although this study was a novel attempt to compare the physiological characteristics of CMP and BGN athletes through a comprehensive assessment, it was not without its limitations. The sample size was a limiting factor of this study, although the overall effects were great enough to observe statistically significant differences. A larger sample would clearly provide better insights into the effects of HIFT. The lack of a non-exercising control group represents a further limitation. Another challenge was represented by the limited observational time points and the fact that we could not assess BGN athletes before they enrolled in the HIFT program. Finally, the selection of suitable testing protocols for this group of athletes represented another challenge and underlines the importance of taking into consideration the population's physical fitness characteristics and type of training, whether applied to elite athletes (P. E. Adami et al., 2015; P. E. Adami et al., 2019), amateur (Sirico et al., 2019) or patients (Ceccarelli et al., 2019), when investigating physiological adaptations to specific training modalities.

The current study provides a clarifying perspective of the early effects of HIFT programmes. However, similarly comprehensive longitudinal studies, with a sufficiently long timeline, would allow for a better understanding of the rate and degree of the physiological adaptations. Future studies should also focus on a more extensive range of fitness components that are pertinent to the sport. Speed and agility, for instance, are essential for many of the technical and repetitive actions performed in HIFT, but these attributes, so far, have received limited research attention.

CONCLUSIONS

The present study shows that competitive HIFT athletes have higher aerobic fitness and strength than a group of age- and gender-matched beginner HIFT athletes. The differences may be attributed to the technical skills acquired overtime by competitive athletes and not only to the physiological adaptations induced by the specific training methodology. The lack of differences in anaerobic capacity is likely due to an early and faster improvement among beginner athletes, compared to other physiological parameters.

AUTHOR CONTRIBUTIONS

PEA, and AM contributed to the conception or design of the work. PEA, JER, NM and AM contributed to the acquisition, analysis, or interpretation of data for the work. PEA and AM drafted the manuscript. PEA, JER, NM and AM critically revised the manuscript. All gave final approval for publication on the Journal of Human Sport and Exercise and agree to be accountable for all aspects of work ensuring integrity and accuracy.

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