© Idōkan Poland Association
"IDO MOVEMENT FOR CULTURE. Journal of Martial Arts Anthropology",
Vol. 20, no. 2 (2020), pp. 24–32
DOI: 10.14589/ido.20.2.4

KINESIOLOGY

Alex Ojeda-Aravena[1(ABCDEFG)], Tomas Herrera-Valenzuela[2,3(DEF)], Jose Manuel Garcia Garcia[4(DEF)], Rodrigo Ramirez-Campillo[1(ACDEFG)]

[1] Laboratory of Human Performance, Quality of Life and Wellness Research Group, Department of Physical Activity Sciences, Universidad de Los Lagos, Osorno (Chile)

[2] Laboratory of Sciences of Physical Activity, Sports and Health, Faculty of Medical Sciences, Universidad de Santiago de Chile, Santiago (Chile)

[3] School of Sports and Physical Activity Sciences, Faculty of Health, Universidad Santo Tomas (Chile)

[4] Faculty of Sport Sciences, Sport Training Laboratory, University of Castilla-La Mancha, Toledo (Spain)

Corresponding author: Rodrigo Ramirez-Campillo
Laboratory of Human Performance, Quality of Life and Wellness Research Group,
Department of Physical Activity Sciences, Universidad de Los Lagos, Osorno, Chile.
e-mail: r.ramirez@ulagos.cl

Six weeks of HIIT based on repeated 5-meter sprints vs. countermovement jumps: effects on physical performance among karate athletes. A pilot-study

Submission: 7.05.2019; acceptance: 4.10.2019

Key words: combat sports, martial arts, physical conditioning, performance

Abstract

Background. The *kumite* section or karate *kumite* is characterized by high-intensity activity, including explosive actions.
Problem and Aim. Determine the magnitude of the effect on the physical performance of karate athletes of the application of two protocols: HIIT-SPRINT and HIIT-JUMP performed at the beginning of a training session (20 minutes) for six weeks.
Methods. Both the HIIT-JUMP and HIIT-SPRINT group underwent a six-week HIIT program, while the CONTROL group continued with their regular karate training. The athletes performed the following tests: squat jump, countermovement jump, 5m and 10m line speed, change of direction, aerobic capacity and body composition.
Results. Fat mass (kg) decreased in the HIIT-JUMP group (ES = -0.63), while the HIIT-SPRINT group reduced the percent of body fat (ES = -0.85). Jump height for the squat and countermovement jumps increased in the HIIT-SPRINT group (ES = 0.82 and 0.94, respectively) and 10-m test (ES = -1.14) and change in direction (ES = -0.60) times were reduced. The HIIT-JUMP group decreased their times for the 5-m and 10-m tests (ES = -0.97 and -1.07, respectively). The HIIT SPRINT group improved in the 5-m test compared to the CONTROL group (ES = 0.62). Conclusions. These results suggest that both HIIT modalities offer specific adaptations, and could be considered as complementary to the training of athletes.

Introduction

The *kumite* section or karate *kumite* is characterized by high-intensity activity, including explosive and intermittent actions that last between 0.3 and 2.1 seconds (time: pause 19:8s; 1:2) [Beneke *et al.* 2004] which requires great technical and tactical skill [Loturco *et al.* 2014]. High cardiorespiratory fitness, including oxidative predominance via the ATP-PC pathway and, to a lesser extent, the glycolytic system [Beneke *et al.* 2004] is needed to cope with the metabolic demand during combat and recovery [Chaabene *et al.* 2012]. *Kumite* is also a sport characterized by body weight, thus physical performance and body composition play an important role in success within the discipline [Chaabene *et al.* 2012].

In this sense, and given that maximum performance depends on high-speed kinetic application of a body segment in a short period of time, it has been suggested that the explosive force and the maximum speed of the lower train are critical in the speed of travel [Ravier, Grappe, Rouillon 2004] and in the acceleration of hits [Loturco *et al.* 2014], requiring the application of specific training methods that develop these characteristics.

In this regard, few studies have reported the effects of different training methods on the development of the physical and physiological characteristics of karate athletes. Training methods evaluated include specific aerobic exercises [Lemma 2014], plyometric / sprint [Davaran, Elmieh, Arazi 2014; Margaritopoulos *et al.* 2015], high intensity interval training (HIIT) [Ravier *et al.* 2009] and strength training [Reza *et al.* 2014].

HIIT is a specific training method for sports in which events last between 1 and 8 minutes and where energy is obtained by the interaction of the oxidative and glycolytic systems [Laursen 2010], such as in karate. HIIT induces adaptations to body composition, cardiorespiratory fitness, aerobic and anaerobic metabolic characteristics [Laursen, Jenkins 2002], neuromuscular and functional performance variables [Kinnunen, Piitulainen, Piirainen 2017] required in *kumite*, which favor execution of explosive motor patterns.

Although HIIT is usually applied on a cycle ergometer [Laursen 2010]; new modalities are based on Sprint Interval Training (SIT) (6 repeated "all-out" efforts for 30 s separated by 4 minutes of recovery) [Buchheit, Laursen 2013], performed in a race [Kinnunen *et al.* 2017] and through repeated jump intervals or Jump Interval Training (JIT) [Ache-Dias *et al.* 2015].

The use of explosive jumps has proven to be effective in improving strength, force, sprinting, coordination, flexibility, preventing injuries, as well as improving aerobic fitness and muscular endurance through neuromuscular adaptations [Booth, Orr 2016]. Among karate athletes, we know of only one study that has used plyometric jumps previously. Jumps were used in combination with repeated sprints based on races made after the usual karate session and results indicate increases in physical performance [Davaran *et al.* 2014]. Similar effects with plyometric training have been reported for other sports, such as Taekwondo [Singh, Boyat, Sandhu 2015] and Muay-Thai [Turner 2009]. However, and in accordance with the above, no studies have been documented for the karate discipline that have used JIT-based plyometric jumps in a similar way to the study conducted by Kinnunen *et al.* [2017], using SIT based on repeated 5-minute races, during the training session. The objective of this study was to determine the magnitude of the effect on physical performance of the application of two protocols: HIIT-SPRINT and HIIT-JUMP performed at the beginning of the session (20 minutes) for six weeks among karate athletes.

Material and Methods

Participants

Nine male athletes (15.6 ± 2.4 years, 167.3 ± 5.4 cm, 63.3 ± 7.5 kg) belonging to three national level Karate schools affiliated with the Chilean Karate Sports Federation voluntarily participated in the study. To be included, they had to meet the following inclusion criteria: i) systematic training for more than two years, at least three times a week, ii) uninterrupted training prior to being included in the study for ≥ 6 months, with no musculoskeletal injuries. Using a randomized controlled design, the participants were randomized into three groups; 1) interval training with repeated countermovement jumps (HIIT-JUMP, 3 subjects), 2) interval training with repeated sprints based on repeated 5m runs (HIIT-SPRINT, 3 subjects) and 3) a CONTROL group (3 subjects). Athletes were informed about the risks and benefits of the study by signing an informed consent before beginning the evaluation. The study was conducted according to the Declaration of Helsinski and the Research Proposals Evaluation Committee of the Department of Physical Activity Sciences, University of Los Lagos.

Procedures and measures

Both the HIIT-JUMP and HIIT-SPRINT groups underwent a six-week HIIT program, while the CONTROL group continued with their regular karate training. Two days before and after the six-week period, the athletes performed the following jumping tests: the squat jump and the countermovement jump using an electronic contact system (Ergojump; Globus, Codogne, Italy) that has a precision of 0.001 s (0.1 cm). Linear speed was measured for 5 and 10m and change of direction via the Illinos Test through automatic timing with electronic photocells (Brower Timing System, Salt Lake City, UT) that have a precision of 0.001s. Aerobic Capacity was measured using a 20m Shuttle-Run Test. Anthropometry was measured using a stadiometer (Bodymeter 206, SECA, Germany at 0.1 cm) and body composition was also recorded (InBody120, tetrapolar 8-point tactile electrodes system, model BPM040S12F07, Biospace, Inc., USA , to 0.1 kg).

During the week prior to the start of the evaluation, participants were acclimated to the procedures (a training session prior to the measurement week) to reduce the effects of learning. Before and after the intervention period, the tests were performed with more than 24 hours of recovery from the last physical training and were completed in the same order, at the same time of day (between 5:00 and 7:00 pm), with the same sportswear and conducted by the same evaluator, blinded with respect to training group. All karate athletes were instructed to: i) sleep well (≥ 8 h) before each day of testing, ii) have a meal rich in carbohydrates and be well hydrated before the evaluation, iii) not consume energy drinks prior evaluation. Participants were motivated through strong verbal stimulus (i.e., "come on", "you can do it") to give their maximum effort during the tests, in addition to performance feedback. Evaluations were conducted in one day, in the following order: anthropometry, body composition, squat jump, countermovement jump, linear speed (5- and 10-m), change of direction (Illinois test), and finally the 20m multistage shuttle run. The best performance score of three attempts was recorded, except for the 20m multistage shuttle run test. Prior to test execution, a ten-minute general warm-up was used (e.g., submaximal runs with change of direction, 20 vertical jumps and 10 horizontal submaximal jumps). In addition, the athletes performed a specific warm-up in two submaximal jumps or sprint attempts, with the exception of the 20m multistage shuttle run where they performed a one minute warm-up. Between each test, adequate recovery was ensured, with at least 5 minutes of rest.

Training program

A six-week program was developed with three training sessions per week. The experimental groups trained the first 20 minutes of the training session supervised by ad-hoc professionals, who ensured correct execution of the exercises. After these first 20-minutes, athletes joined the normal training session where they conducted technical and tactical exercises of moderate intensity. The CONTROL group continued with their regular training during the first 20 minutes of training. Study subjects were instructed to rest properly each day before the training session. Each training session began with a 5-minute warm-up consisting of dynamic stretching and joint mobility exercises. All sessions were performed on a rubber floor, with bare feet.

The HIIT-JUMP training sessions consisted of the execution of intermittent series of maximum "all out" countermovement jumps repeated for 30 seconds with 2.5 minutes of rest similar to previous protocols [Racil *et al.* 2015]. The HIIT-SPRINT training sessions consisted of the execution of intermittent series of repeated "all-out" 5m (roundtrip) sprints, for 30 seconds, with 2.5 minute walking pauses. Both exercise protocols gradually increased exercise volume from 6 to 8 sets on a weekly basis. During the last two weeks, training loads were reduced to 6 sets. Participants were verbally instructed to perform the exercises at maximum intensity with a "subjective perception of effort" from 8 to 10 on a 1-10 scale [Foster 1998] (Figure 1.).

Statistical Analysis

Statistical analysis was performed using GRAPHPAD PRISM (version 6.0, San Diego, California). All values were reported as median, 25% and 75% percentile. The relative changes (%) of the performance were expressed using Cohen´s d for effect size (ES) and were expressed with the 90% confidence interval. For all measurements, an intra-class coefficient was used to observe reliability of 0.96-0.98. The thresholds to determine ES magnitude were 0.20, 0.60, 1.2 and 2.0 for small, moderate, high, and very high, respectively [Hopkins *et al.* 2009].

Results

After training, the HIIT-JUMP group decreased fat mass (kg) (ES = moderate), while the HIIT-SPRINT group reduced fat% (ES = moderate). Body weight was not modified for any study group (ES = small) (table 1).

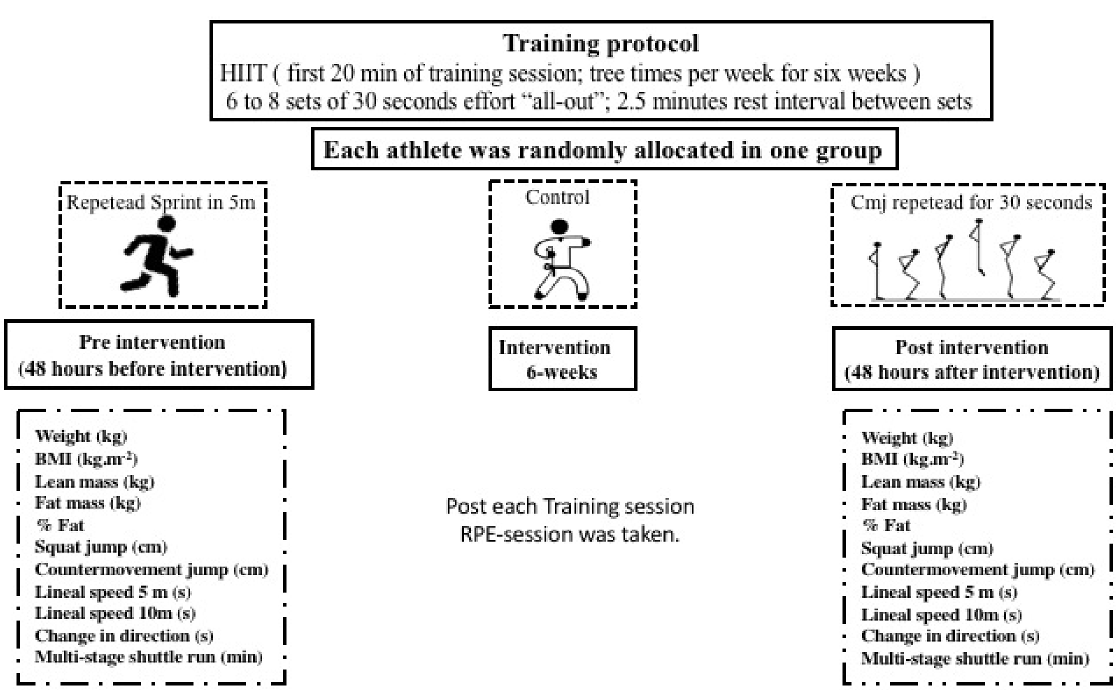


Image 1. Experimental Design

Table 1. Training effect (90% confidence interval) on anthropometric and body composition characteristics among study groups: Control (n=3), HIIT-JUMP (n=3), HIIT-SIT (n=3).

Variable	Pre-test Median [P_{25}; P_{75}]	Pos-test Median [P_{25}; P_{75}]	% change (90% confidence interval)	Effect size (90% confidence interval)
CONTROL				
Weight (kg)	71.7 [59.2; 72.3]	72.6 [58.8; 72.6]	3 (-1.3 a 2.0)	0.02 (-0.06 a 0.10) ❡
BMI (kg.m^{-2})	26.2 [22; 29]	26.3 [21.9; 29.5]	0.2 (-0.3 a 0.7)	0.03 (-0.05 a 0.11) ❡
Lean mass (kg)	26.4 [25.1; 29.7]	28.3[26.8; 30.2]	5.2 (0.1 a 10.5)	0.39 (0.01 a 0.77) ❡
Fat mass (kg)	26.1 [12.1, 29.2]	24.3 [8.3; 28.2]	-14.9 (-38.0 a 16.8)	-0.16 (0.47 a 0.15) ❡
% Fat	20.5 [20.5, 36.]	19.6 [14.1; 33.5]	-21.5 (-25.6 a -17.2)	-0.44(-0.54 a -0.35) ❡
HIIT-JUMP				
Weight (kg)	60 [60; 61.3]	61.3 [58.6; 66.1]	3 (-4.0 a 3.6)	-0.03 (-0.39 a 0.34) ❡
BMI (kg.m^{-2})	22 [21; 21.8]	22 [22; 22.3]	0.4 (-0.6 a 1.4)	0.47 (-0.83 a 1.77) ❡
Lean mass (kg)	28.5 [27.3; 31.6]	28.2 [28; 32.3]	1.2 (-3.2 a 5.8)	0.09 (-0.24 a 0.42) ❡
Fat mass (kg)	10.5 [9.4; 11.1]	8.2 [8.6; 10.5]	-10.2 (-21.5 a 2.9)	-0.63 (-1.42 a 0.17) †
% Fat	15.8 [15.6; 18.3]	15 [13; 17.1]	-9.6 (-21.4 a 4.0)	0.50 (-1.19 a 0.19) ❡
HIIT-SPRINT				
Weight (kg)	58.7 [49; 72.2]	56.7 [50; 71.6]	0.8 (-5.2 a 3.9)	-0.02(-0.16 a 0.12) ❡
BMI (kg.m^{-2})	20 [18; 22.3]	19.4 [18.4; 22.1]	-0.1 (-1.0 a 0.7)	-0.04 (-0.28 a 0.20) ❡
Lean mass (kg)	27.4 [23.9; 34.6]	27.5 [24.9; 35.9]	2.8 (-0.7 a 6.4)	-0.08 (-0.02 a 0.19) ❡
Fat mass (kg)	9.4 [5.9; 11.1]	7.3 [4.8; 8.5]	-21.5 (-25.6 a -17.2)	-0.44(-0.54 a -0.35) ❡
% Fat	15.4 [11.9; 16]	11.8 [9.7; 12.9]	-20.4 (-24.7 a -15.9)	-0.85 (-1.06 a -0.64) †

BMI= Body Mass Index. ❡, †, § denotes small, moderate and large effect size, respectively.

Table 2. Training effects (90% confidence interval) of performance variables in CONTROL (n=3), HIIT-JUMP (n=3), and HIIT-SIT (n = 3) groups.

Variables	Pre-test median [P_{25}; P_{75}]	Pos-test median [P_{25}; P_{75}]	% change (90% confidence interval)	Effect size (90% confidence interval)
Squat Jump (cm)				
CONTROL	24 [16; 29]	28 [16;30]	6.5 (-7.1 a 22.0)	0.11 (-0.13 a 0.35) ❡
HIIT-JUMP	31 [29; 32]	39 [39; 37]	5.0 (-21.1 a 39.7)	0.30 (-1.46 a 2.06) ❡
HIIT-SPRINT	28 [27; 31]	31 [30; 32]	8.3 (-3.8 a 21.9)	0.82 (-0.40 a 2.04) †
Countermovement Jump (cm)				
CONTROL	31 [18; 31]	30 [17; 34]	0.1 (-12.6 a 14.6)	0.00 (-0.22 a 0.23) ❡
HIIT-JUMP	33 [11; 33]	33 [30; 36]	4.1 (-3.3 a 12.1)	0.28 (-0.23 a 0.78) ❡
HIIT-SPRINT	30 [28; 30]	33 [30; 36]	12.2 (-5.2 a 33.0)	0.94 (-0.44 a 2.31) †
Linear speed -5 m (s)				
CONTROL	1.1 [1.0; 1.3]	1.0 [0.90; 1.0]	14.6 (-26.8 a -0.4)	0.90 (-1.77 a -0.02) †
HIIT-JUMP	1 [0.9; 1.1]	0.9 [0.8; 0.9]	-12.1 (-30.8 a 11.7)	-0.97 (-2.78 a 0.83) †
HIIT-SPRINT	1 [1; 1.1]	1 [0.9; 1]	-4.0 (-9.6 a 1.9)	-0.42 (-1.04 a 0.20) ❡
Linear speed -10 m (s)				
CONTROL	1.9 [1.7; 2.4]	1.9 [1.7; 2.9]	6.9 (-40.0 a 90.4)	0.15 (-1.16 a 1,47) ❡
HIIT-JUMP	1.9 [1.8; 2.0]	1.6 [1.6; 1.9]	-11.7 (-25.0 a 3.9)	-1.07 (-2.46 a 0.33) †
HIIT-SPRINT	1.9 [1.8; 1.9]	1.7 [1.6: 1.8]	-9.0 (-14.2 a -3.5)	-1.14 (-1.86 a -0.43) †
Change in direction (s)				
CONTROL	17.3 [15.5; 17.5]	15.8 [15.2; 16.6]	-5.3 (11.9 a 1.8)	-0.54 (-1.27 a 0.18) ❡
HIIT-JUMP	16.5 [16.5; 18.2]	14.7 [14.4; 16.2]	-11.6 (-13.4 a -9.6)	-1.20 (-1.40 a -0.99) §
HIIT-SPRINT	15.5 [14.69; 17.78]	1.6 [14.1; 15.5]	-7.7 (-15.2 a 0.5)	-0.60 (-1.23 a 0.03) †
Multi-Stage Shuttle Run (min)				
CONTROL	7 [5; 7]	7 [4; 9]	0.9 (-32.3 a 50.6)	0.02 (-0.69 a 0.72) ❡
HIIT-JUMP	8 [6; 10]	8 [6; 9]	-3.5 (-12.9 a 7.0)	-0.09 (0.34 a 0.16) ❡
HIIT-SPRINT	8 [6; 10]	8 [8;9]	6.3 (-24.6 a 49.7)	0.19 (-0.86 a 1.23) ❡

❡, †, § denotes small, moderate and large effect size, respectively.

For within-group differences, the CONTROL group decreased the 5-m test time (ES = moderate). The HIIT-SPRINT group increased jump height for the squat and countermovement jump tests (ES = moderate) and reduced their 10-m (ES = moderate) and change of direction test times (ES = moderate). The HIIT-JUMP group decreased the times for the 5-m and 10-m tests (ES = moderate) (table 2).

In group comparisons, the HIIT-SPRINT group decreased the 5-m execution time compared to the CONTROL group (ES = moderate) (table 3).

Additionally, jumping height in the countermovement test and the initial 5-m linear speed improved in the HIIT-SPRINT group (ES = moderate for both tests), compared to the HIIT-JUMP group (table 4).

Discussion

The objective of this study was to determine the magnitude of effect on physical performance after the application of two HIIT protocols (HIIT-SPRINT and HIIT-JUMP) performed by karate athletes at the beginning of a training session (20 minutes) over six weeks. Before and after the intervention, body composition and measures of physical performance relevant for the sport [Chaabene *et al.* 2012] were evaluated. The main findings of the study were that, after training, both HIIT protocols were effective in modifying body composition. The HIIT-JUMP group reduced fat mass (kg) and the HIIT-SPRINT group showed reductions in % body fat. The HIIT-SPRINT group improved jump height in the countermovement and squat jumps, reduced the execution time in the linear speed test (10 m) and change of

Table 3. Training effects (90% confidence interval) on performance variables between CONTROL-JUMP and CONTROL-SPRINT groups.

	Magnitude of change observed CONTROL vs HIIT-JUMP		Magnitude of change observed CONTROL vs HIIT-SPRINT
Body composition variables	**% change (90% confidence interval)**	**Effect size (90% confidence interval)**	**% change (90% confidence interval)**
Weight (kg)	-0.6 (-4.6 a 3.6)	-0.04(-0.29 a 0.22) ¶	-1.1 (-5.8 a 3.9)
BMI (kg.m^{-2})	1.2 (-3.8 a 6.4)	-0.05 (-0.17 a 0.28) ¶	-1.1 (-5.8 a 3.8)
Lean mass (kg)	-3.8 (-8.8 a 1.5)	-0.26 (-0.63 a 0.11)¶	-2.3 (-7.0 a 2.6)
Fat mass (kg)	5.6 (-25.2 a 49.0)	-0.06 (-0.33 a 0.46)¶	-7.8 (-33.1 a 27.2)
% fat	6.9 (-23.5 a 49.3)	0.12 (-0.49 a 0.74)¶	-5.9 (-30.9 a 28.1)
Performance variables			
Squat Jump (cm)	-1.4 (-28.2 a 35.4)	-0.03 (-0.72 a 0.66)¶	1.7 (12.1 a 17.7)
Countermovement Jump (cm)	4.0 (-8.1 a 17.8)	0.10 (-0.21 a 0.40)¶	12.2 (-5.8 a 33.6)
Linear speed-5 m (s)	2.9 (-18.2 a 29.5)	0.13 (-0.93 a 1.20)¶	12.4 (-4.7 a 32.6)
Linear speed-10 m (s)	-17.4 (-54.7 a 50.5)	0.49 (-2.01 a 1.0.4)¶	-14.9 (52.4 a 52.1)
Change in direction (s)	-6.6 (-13.4 a 0.7)	0.46 (-0.99 a 0.06) ¶	-2.6 (-10.9 a 6.6)
Multi-Stage Shuttle Run (min)	-4.4 (-36.7 a 44.6)	-0.11 (-1.10 a 0.89) ¶	5.3 (31.2 a 61.0)

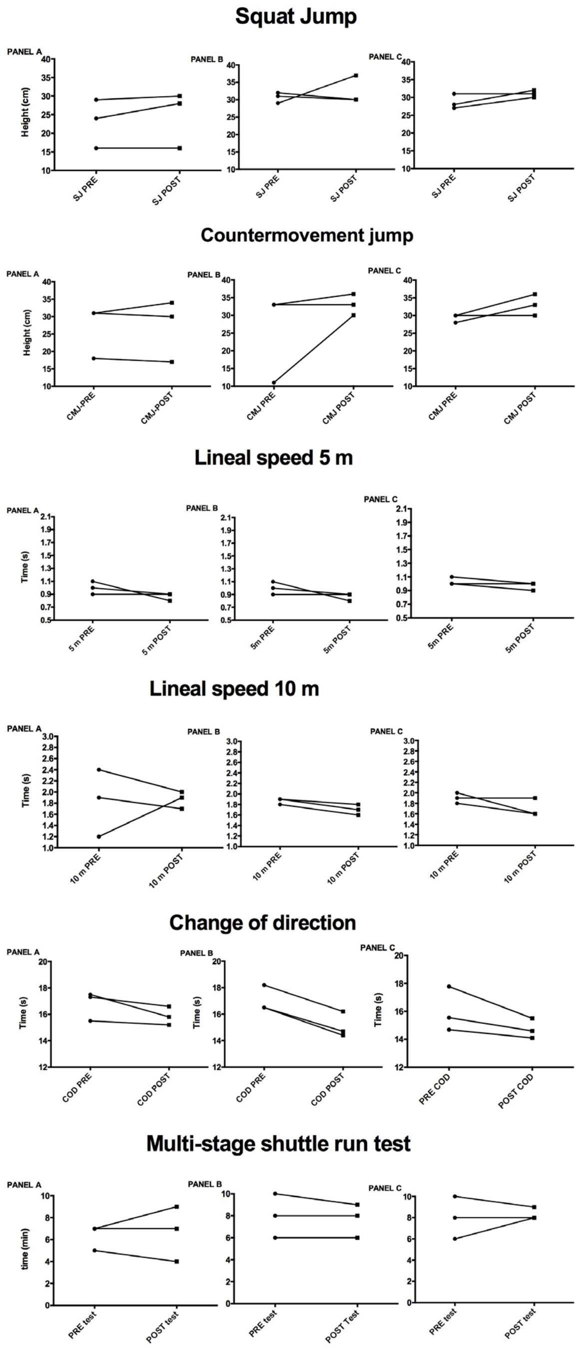
BMI =Body mass index; ¶, †, § denotes small, moderate and large effect size, respectively.

Table 4. Effects of HIIT (90% confidence interval) on body composition and physical performance between HIIT-JUMP and HIIT-SPRINT groups

	Magnitude of change observed HIIT-JUMP vs HIIT-SPRINT	
Body composition variables	**% change (90% confidence interval)**	**Effect size (90% confidence interval)**
Weight (kg)	0.5 (-5.2 a 4.4)	0.02 (-0.23 a 0.19) ¶
BMI (kg.m^{-2})	2.3 (-7.2 a 3.0)	-0.16 (-0.52 a 0.20) ¶
Lean mass (kg)	1.5 (-3.0 a 6.2)	0.07 (-0.14 a 0.27) ¶
Fat mass (kg)	12.6 (-24.5 a -12.6)	-0.32 (-0.67 a 0.03) ¶
% fat	12.0 (-24.3 a 2.3)	0.52 (-1.3 a 0.09) ¶
Performance variables		
Squat Jump (cm)	3,1 (-24.3 a 40.5)	0.26 (-2.38 a 2.91)¶
Countermovement Jump (cm)	7.8 (-10.4 a 29.7)	0.64(-0.93 a 2.20) †
Linear speed-5 m (s)	8.4 (-28.5 a 17.2)	0.81 (-3.07 a 1.46) †
Linear speed-10 m (s)	3.1 (-13.3 a 22.6)	0.53 (-2.51 a 3.57) ¶
Change in direction (s)	4.1 (-12.2 a 4.6)	0.30 (0.93 a 0.33) ¶
Multi-Stage Shuttle Run (min)	10.1 (-23.1 a 57.4)	0.24 (-0.24 a -0.65) ¶

BMI =Body mass index; ¶, †, § denotes small, moderate and large effect size, respectively.

Image 2. Individual changes in perfomance variables



Panel A, B and C represent CONTROL; HIIT-JUMP; HIIT-SPRINT groups respectively.

direction. Meanwhile, the HIIT-JUMP group decreased the execution times in the linear speed tests (5 and 10 m). These results suggest that both HIIT modalities offer specific adaptations, and could be considered as complementary to the training of athletes.

In relation to the results of the jumping tests, our study reported that the HIIT-SPRINT group improved vertical jumping ability in the squat jump by 8.3% and the countermovement jump by 12.2%. Our results are in agreement with other studies that have reported increases in height in these jumps after training programs based on repeated supramaximal sprints (160-180% Vo2max) [Buchheit, Laursen 2013], or "all-out" interval efforts for 30s [Islam, Townsend, Hazell 2016], during 2.5 weeks in squat jumps (4.7%) [Kinnunen *et al.* 2017], 5 weeks in squat (5.9%) and countermovement (9.21%) jumps [Garcia-Pinillos *et al.* 2017] and after 4 weeks by repeated jumps over 30s in countermovement jumps (~4.7%) [Ache-Dias *et al.* 2015] and in the short-term among karate athletes (3%) [Margaritopoulos *et al.* 2015].

Other protocols executed on a cycle ergometer for 6 weeks [Creer *et al.* 2004], rowing and performing multimodal circuits with strength exercises (bench press, squat and deadlift) [Buckley *et al.* 2015] have also been effective. However, other authors have not observed significant differences in performance in the countermovement jump through HIIT with repeated sprints in sports with intermittent characteristics such as tennis [Fernandez-Fernandez *et al.* 2012], handball [Buchheit *et al.* 2010] and soccer [Ferrari Bravo *et al.* 2008]. On the other hand, programs based on repeated countermovement jumps, applied in the short-term for karate athletes, have been effective in increasing jump height, which suggests that it may be an efficient strategy to use before competitions [Margaritopoulos *et al.* 2015]. Neuromuscular adaptations measured by surface electromyography in the plantar flexor muscles (soleus and tibialis anterior) have been documented. Specifically, an increased rate of force development and decreased anterior tibial coactivation, an increase in maximum voluntary contraction force and an increase in nerve conduction (v-waves) [Kinnunen *et al.* 2017], in addition to results observed by Creer *et al.* [2004], such as a greater fibrillary recruitment and greater synchronization in the vastus lateralis muscle, could explain the effectiveness of the HIIT to improve explosive strength. In addition, HIIT and, in particular SIT, is effective in improving explosive strength by recruiting type 2 fibers, given its maximal intensity (> 100% of individual $VO2_{max}$ velocity) [Sloth *et al.* 2013].

Our study reported that the HIIT-JUMP group compared to the CONTROL group improved initial displacement speed by reducing displacement time in the 5-m test. This has been similarly observed after the application of exercise protocols derived from the countermovement jump [Turner, Jeffreys 2010], applied over 6 [Lockie *et al.* 2012], 8 [Rimmer, Sleivert 2000], and 12 weeks [Chaouachi *et al.* 2014]. According to the above, and consistent with our results, training based on explosive jumps is recognized as a method to develop muscle function [Flanagan, Comyns 2008], speed and anaerobic power [Ramirez-Campillo *et al.* 2018]. In addition to other variables related to physical performance, such as agility [Davaran *et al.* 2014] and force [Ramirez-Campillo, Andrade, Izquierdo 2013]. Among the adaptations in response to this type of training that would explain our results include the reduction of the transition time between the eccentric and concentric phases (potentiation effect) [Flanagan, Comyns 2008], changes in the structural characteristics of the muscle-tendon complex, and the type of fiber and neural activation [Markovic, Mikulic 2010]. On the other hand, HIIT protocols based on repeated sprints, a variant of SIT characterized by execution times of 3 to 7 s with recovery intervals generally less than 60-s, [Buchheit, Laursen 2013] have been effective in improving the ability to sprint 5- and 10-m in a way similar to our results [Lockie *et al.* 2012].

HIIT and SIT are effective training methods to improve body composition. In particular, in the reduction of total fat mass, visceral and abdominal fat [Astorino, Schubert 2018]. Among the potential explanations for these adaptations is that they could be related to a greater lipolysis as a result of the activation of the b-receptors in response to high work intensities (>60% $VO2_{máx}$) and the resulting activation of the lipase-sensitive hormone, which generates triglyceride hydrolysis [Zouhal *et al.* 2008] and consequently an increase in fat oxidation after training, which is also influenced by increased post-exercise oxygen consumption [Maillard *et al.* 2017]. In turn, peripheral muscle adaptations related to increased fat oxidation, such as increased mitochondrial content, function and enzymatic content [Gibal, Jones 2013] could explain these modifications. Specifically in combat sports, a study conducted in judo athletes [Lee *et al.* 2015], reported that 12 weeks of HIIT decreased the percentage of fat and body mass in the group that performed 6 to 10 sprints at 80% to 90% of the maximum sprint speed over 30 sec with 4 minutes of rest. Another intervention conducted among judo athletes [Kim *et al.* 2011] showed no changes in body composition, using the same HIIT protocol for 8 weeks. Additionally, another study conducted among judo athletes who used a HIIT protocol for 4 weeks, with a temporary structure similar to competition (2 blocks x 10 sets x 20 seconds of activation with 10 seconds of pause and 5 minutes of rest between blocks) also did not modify body composition [Franchini *et al.* 2016]. On the other hand, in the case of taekwondo, an intervention with HIIT for 4 weeks, decreased body mass, but increased fat percentage [Monks *et al.* 2017]. Thus, body composition effects of HIIT among combat sport athletes are not conclusive, our research is the first study conducted among karate athletes that shows benefits of HIIT in the decrease of percentage of body fat. Differences in study results are likely due to different protocols used, intervention length and the competitive level of the participant athletes.

Regarding $VO2_{max}$, there are reported positive effects of HIIT in boxing, *judo*, Olympic wrestling, *taekwondo*, and *karate* [Ravier *et al.* 2009; Franchini, Cormack, Takito 2019]. Specifically, among karate athletes, only Ravier *et al.* [2009] showed effects on $VO2_{max}$, where athletes performed a HIIT protocol, twice a week, for 6-7 weeks, 7 to 9 sets of 20 seconds each at 140% maximum aerobic speed, with 15 seconds recovery between intervals. Not all the interventions applied to combat sports athletes have achieved improvements in $VO2_{max}$ [Franchini *et al.* 2016; Kim *et al.* 2011]. Similarly, our study showed no improvement in $VO2_{max}$. It is likely that 20 minutes of intervention was not enough to generate significant adaptations among participants. Another possible explanation is that the athletes did not make an all-out effort, although we have no way of confirming this hypothesis.

Conclusions

Within the limitations of the study, it is important to mention the sample size. Our study had seven subjects. However, as far as we know, this is the first study to investigate the adaptations of HIIT-SPRINT vs. HIIT-JUMP among karate athletes, therefore, it provides preliminary information for future work with larger samples. Finally, our study has practical applications. Coaches of karate athletes may consider using HIIT-JUMP and HIIT-SPRINT exercises in the 6 weeks prior to competition, with the aim of improving neuromuscular variables, which can affect competition results.

References

1. Ache-Dias J., Dellagrana R.A., Teixeira A.S., Dal Pupo J., Moro, A.R. (2015), *Effect of jumping interval training on neuromuscular and physiological parameters: A randomized controlled study*, “Applied Physiology, Nutrition, and Metabolism”, vol. 41, no. 1, pp. 20–25; doi: 10.1139/apnm-2015-0368.
2. Astorino T.A., Schubert M.M. (2018), *Changes in fat oxidation in response to various regimes of high intensity interval training (HIIT)*, “European Journal of Applied Physiology”, vol. 118, no. 1, pp. 51–63; doi: 10.1007/s00421-017-3756-0.
3. Beneke R., Beyer T., Jachner C., Erasmus J., Hutler M. (2004), *Energetics of karate kumite,* “European Journal of Applied Physiology”, vol. 92, no. 4-5, pp. 518-523; doi: 10.1007/s00421-004-1073-x.
4. Booth M.A., Orr R. (2016), *Effects of Plyometric Training on Sports Performance*, “The Journal of Strength & Conditioning Research”, vol. 38, no. 1, pp. 30–37; doi: 10.1519/SSC.0000000000000183.
5. Buchheit M., Laursen P.B. (2013), *High-intensity interval training, solutions to the programming puzzle*, “Sports Medicine”, vol. 43, no. 5, pp. 313–338; doi: 10.1007/s40279-013-0029-x.
6. Buchheit M., Mendez-Villanueva A., Quod M., Quesnel T., Ahmaidi S. (2010), *Improving acceleration and repeated sprint ability in well-trained adolescent handball players:*

Speed versus sprint interval training, "International Journal of Sports Physiology and Performance", vol. 5, no. 2, pp.152–164; doi: 10.1055/s-2007-989371.

7. Buckley S., Knapp K., Lackie A., Lewry C., Horvey K., Benko C., Butcher S. (2015), *Multimodal high-intensity interval training increases muscle function and metabolic performance in females*, "Applied Physiology, Nutrition, and Metabolism", vol. 40, no. 11, pp. 1157–1162; doi: 10.1139/apnm-2015-0238.
8. Chaabene H., Hachana Y., Franchini E., Mkaouer B., Chamari K. (2012), *Physical and Physiological Profile of Elite Karate Athletes*, "Sports Medicine", vol. 42, no. 10, pp. 829-843; doi: 10.2165/11633050-000000000-00000.
9. Chaouachi A., Hammami R., Kaabi S., Chamari K., Drinkwater E.J., Behm D.G. (2014), *Olympic weightlifting and plyometric training with children provides similar or greater performance improvements than traditional resistance training*, "The Journal of Strength & Conditioning Research", vol. 28, no. 6, pp.1483–1496; doi: 10.1519/JSC.0000000000000305.
10. Creer A.R., Ricard M.D., Conlee R.K., Hoyt G.L., Parcell A.C. (2004), *Neural, metabolic, and performance adaptations to four weeks of high intensity sprint-interval training in trained cyclists*, "International Journal of Sports Medicine", vol. 25, no. 2, 92-98; doi: 10.1055/s-2004-819945.
11. Davaran M., Elmieh A., Arazi H. (2014), *The effect of a combined Plyometric-Sprint Training program on strength, speed, power and agility of karate-ka male athletes*, "Research Journal of Sport Sciences", vol. 2, no. 2, pp. 38–44.
12. Fernandez-Fernandez J., Zimek R., Wiewelhove T., Ferrauti, A. (2012), *High-intensity interval training vs. Repeated-sprint training in tennis*, "The Journal of Strength & Conditioning Research", vol. 26, no. 1, pp. 53–62; doi: 10.1519/JSC.0b013e318220b4ff.
13. Ferrari Bravo D.F., Impellizzeri F.M., Rampinini E., Castagna C., Bishop D., Wisloff U. (2008), *Sprint vs. Interval training in football*, "International Journal of Sports Medicine", vol. 29, no. 8, pp. 668–674; doi: 10.1055/s-2007-989371.
14. Flanagan E.P., Comyns T.M. (2008), *The use of contact time and the reactive strength index to optimize fast stretch-shortening cycle training*, "The Journal of Strength & Conditioning Research", vol. 30, no. 5, pp. 32–38; doi: 10.1519/SSC.0b013e318187e25b.
15. Foster C. (1998), *Monitoring training in athletes with reference to overtraining syndrome*, "Medicine and Science in Sports and Exercise", vol. 30, no. 7, pp. 1164-1168; doi: 10.1097/00005768-199807000-00023.
16. Franchini E., Cormack S., Takito M.Y. (2019), *Effects of High-Intensity Interval Training on Olympic Combat Sports Athletes' Performance and Physiological Adaptation: A Systematic Review*. "The Journal of Strength & Conditioning Research", vol. 33, no. 1, pp. 242–252; doi: 10.1519/JSC.0000000000002957.
17. Franchini E., Julio U.F., Panissa V.L.G., Lira F.S., Gerosa-Neto J., Branco B.H.M. (2016), *High-Intensity Intermittent Training Positively Affects Aerobic and Anaerobic Performance in Judo Athletes Independently of Exercise Mode*, "Frontiers in Physiology", vol. 7, pp. 268.
18. Garcia-Pinillos F., Camara-Perez J.C., Soto-Hermoso V.M., Latorre-Roman P.A. (2017), *A High Intensity Interval Training (HIIT)-based running plan improves athletic performance by improving muscle power*, "The Journal of Strength & Conditioning Research", vol. 31, no. 1, pp.146–153; doi: 10.3389/fphys.2016.00268.
19. Gibala M.J., Jones A.M. (2013), *Physiological and performance adaptations to high-intensity interval training. En Limits of Human Endurance,* "Karger Publishers", vol. 76, pp. 51–60; doi: 10.1159/000350256.
20. Hopkins W., Marshall S., Batterham A., Hanin J. (2009). *Progressive statistics for studies in sports medicine and exercise science*, "Medicine Science in Sports Exercise", vol. 41, no. 1, pp. 3; doi: 10.1249/MSS.0b013e31818cb278.
21. Islam H., Townsend L.K., Hazell T.J. (2016). *Modified sprint interval training protocols. Part I. Physiological responses*, "Applied Physiology, Nutrition, and Metabolism", vol. 42, no. 4, pp. 339–346; doi: 10.1139/apnm-2016-0478.
22. Kim J., Lee N., Trilk J., Kim E.J., Kim S.Y., Lee M., Cho H.C. (2011), *Effects of Sprint Interval Training on Elite Judoists*, "International Journal of Sports Medicine", vol. 32, no. 12, pp. 929-934; doi: 10.1055/s-0031-1283183.
23. Kinnunen J., Piitulainen H., Piirainen J.M. (2017), *Neuromuscular adaptations to short-term high-intensity interval training in female ice hockey players*, "The Journal of Strength & Conditioning Research", vol. 33, no. 2, pp. 479-485; doi: 10.1519/JSC.0000000000001881.
24. Laursen P.B. (2010), *Training for intense exercise performance: High-intensity or high-volume training?* "Scandinavian Journal of Medicine & Science in Sports", vol. 20, no. 2, pp. 1–10; doi: 10.1111/j.1600-0838.2010.01184.x.
25. Laursen P.B., Jenkins D.G. (2002), *The scientific basis for high-intensity interval training: Optimising training programmes and maximising performance in highly trained endurance athletes*, "Sports Medicine", vol. 32, no. 1, pp. 53-73; doi: 10.2165/00007256-200232010-00003.
26. Lee N., Kim J., Hyung G.A., Park J.H., Kim S.J., Kim H.B., Jung H.S. (2015), *Training Effects on Immune Function in Judoists*, "Asian Journal of Sports Medicine", vol. 6, no. 3; doi: 10.5812/asjsm.24050.
27. Lemma H. (2014), *The Effects of Selected Types of Aerobic Exercise on Enhancing Muscular Endurance, Strength and Flexibility of Young Male Karate Trainees at Boke Tiko Training Center, Ethiopia*, Haramaya University.
28. Lockie R.G., Murphy A.J., Schultz A.B., Knight T.J., de Jonge X.A.J. (2012), *The effects of different speed training protocols on sprint acceleration kinematics and muscle strength and power in field sport athletes*, "The Journal of Strength & Conditioning Research", vol. 26, no. 6, pp. 1539–1550; doi: 10.1519/JSC.0b013e318234e8a0.
29. Loturco I., Artioli G.G., Kobal R., Gil S., Franchini E. (2014), *Predicting punching acceleration from selected strength and power variables in elite karate athletes: A multiple regres-*

sion analysis, “The Journal of Strength & Conditioning Research”, vol. 28, no. 7, pp. 1826–1832; doi: 10.1519/JSC.0000000000000329.
30. Margaritopoulos S., Theodorou A., Methenitis S., Zaras N., Donti O., Tsolakis C. (2015), *The effect of plyometric exercises on repeated strength and power performance in elite karate athletes*, “Journal of Physical Education and Sport”, vol. 15, no. 2, pp. 310; doi:10.7752/jpes.2015.02047.
31. Ramirez-Campillo R., Alvarez C., Garcia-Hermoso A., Ramirez-Velez R., Gentil P., Asadi A., Izquierdo M. (2018), *Methodological Characteristics and Future Directions for Plyometric Jump Training Research: A Scoping Review*, “Sports Medicine”, vol. 48 no. 5, pp. 1059–1081; doi: 10.1007/s40279-018-0870-z.
32. Ramirez-Campillo R., Andrade D.C., Izquierdo M. (2013), *Effects of plyometric training volume and training surface on explosive strength*, “The Journal of Strength & Conditioning Research”, vol. 27, no. 10, pp. 2714–2722; doi: 10.1519/JSC.0b013e318280c9e9.
33. Ravier G., Dugué B., Grappe F., Rouillon J.D. (2009), *Impressive anaerobic adaptations in elite karate athletes due to few intensive intermittent sessions added to regular karate training*, “Scandinavian Journal of Medicine & Science in Sports”, vol. 19, no. 5, pp. 687-694; doi: doi: 10.1111/j.1600-0838.2008.00807.x
34. Ravier G., Grappe F., Rouillon J.D. (2004), *Application of force-velocity cycle ergometer test and vertical jump tests in the functional assessment of karate competitor*, “Journal of Sports Medicine and Physical Fitness”, vol. 44, no. 4, pp. 349.
35. Reza S., Amir S., Bin W., Ahmad S., Ramin S. (2014), *Comparison of the Pattern of Weight Training on Muscle Strength and Endurance in Karate Men*, “Journal of Sports Science”, vol. 2, pp. 214–221; doi: 10.17265/2332-7839/2014.04.007.
36. Rimmer E., Sleivert G. (2000), *Effects of a Plyometrics Intervention Program on Sprint Performance*, “The Journal of Strength & Conditioning Research”, vol. 14, no. 3, pp. 295-301.
37. Singh A., Boyat A.V., Sandhu J. S. (2015), *Effect of a 6 week plyometric training pro-gram on agility, vertical jump height and peak torque ratio of Indian Tae-kwondo players*, “Sport and Exercise Medicine Open Journal”, vol. l, no. 2, pp. 42–46; doi: 10.17140/SEMOJ-1-107.
38. Sloth M., Sloth D., Overgaard K., Dalgas U. (2013), *Effects of sprint interval training on VO2max and aerobic exercise performance: A systematic review and meta-analysis*, “Scandinavian Journal of Medicine & Science in Sports”, vol. 23 no. 6; doi: 10.1111/sms.12092.
39. Turner A.N. (2009), *Strength and conditioning for Muay Thai athletes*, “The Journal of Strength & Conditioning Research”, vol. 31, no. 6, pp. 78–92; doi: 10.1519/SSC.0b013e3181b99603.
40. Zouhal H., Jacob C., Delamarche P., Gratas-Delamarche A. (2008), *Catecholamines and the effects of exercise, training and gender*, “Sports Medicine”, vol. 38, no. 5, pp. 401–423; doi: 10.2165/00007256-200838050-00004.

Sześcio-tygodniowy trening interwałowy o wysokiej intensywności (HIIT) oparty na podstawie powtarzających się 5-metrowych sprintów w zestawieniu ze skokami okrężnymi: wpływ na sprawność fizyczną zawodników karate. Studium pilotażowe

Słowa kluczowe: sporty walki, sztuki walki, kondycja fizyczna, wydajność

Streszczenie
Tło. Sekcja *kumite* lub *karate kumite* charakteryzuje się wysoką intensywnością działania.
Problem i cel. Celem badania było określenie wielkości wpływu zastosowania dwóch protokołów: HIIT-SPRINT i HIIT-JUMP na sprawność fizyczną zawodników karate wykonywane na początku sesji treningowej (20 minut) przez sześć tygodni.
Metody. Zarówno grupa HIIT-JUMP jak i HIIT-SPRINT przeszły sześciotygodniowy program: trening interwałowy o wysokiej intensywności HIIT, natomiast grupa CONTROL kontynuowała swój regularny trening karate. Zawodnicy wykonali testy obejmujące: skok z przysiadem, skok w przeciwnych kierunkach, bieg po linii 5 i 10 m, zmianę kierunku, wydajność aerobową i analizę składu ciała. = -0,85). W grupie HIIT-SPRINT (ES = 0,82 i 0,94) i 10-metrowym teście (ES = -1,14) oraz zmianie kierunku (ES = -0,60) zmniejszyły się czasy skoków. W grupie HIIT-JUMP zmniejszyły się czasy dla testów 5 i 10-metrowych (ES = odpowiednio -0,97 i -1,07). Grupa HIIT SPRINT poprawiła się w teście 5-metrowym w porównaniu do grupy CONTROL (ES = 0,62).
Wnioski. Wyniki te sugerują, że obie metody HIIT oferują szczególne możliwości adaptacyjne i mogą być uznane za uzupełniające do treningu sportowców.