Original Article

Effects of a high-intensity interval training protocol based on functional exercises on performance and body composition in handball female players

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ABSTRACT

The aim of this study is to measure the impact of 8-week high-intensity interval training (HIIT) based on functional exercises on the following variables in handball female players: weight (kg), body mass index (BMI), % fat, jumping (cm), repeated sprint ability (RSA), aerobic capacity. Fourteen female players were randomly assigned either to an experimental group (GE, n=7) which would undertake a "mixed functional HIIT" (combining strength, coordination and plyometric exercises) before training sessions, or to a control group (GC, n=7), in which HIIT was replaced by usual warm-up exercises in the field. The intervention programme lasted 8 weeks, with two training sessions a week. A pre-test and post-test on each variable were carried out. The intra-group GC analysis showed no significant changes between the pre- and post-test in any variable. Figures for the GE, though, showed significant changes: a 3.45% (d=0.67) reduction in % fat of players, RSA execution time went down by 7.22% RSA (d=0.82), and VO2max increased by 6.19% (d=0.78). These results seem to point to "mixed functional HIIT" as an effective strategy to improve body composition

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and performance in female handball players. **Key words:** TEAM SPORT, HIIT, VO2MAX, DEVELOP AND POWER, TIME-EFFICIENT TRAINING, REPEAT SPRINT ABILITY RSA.

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INTRODUCTION

Handball is a collective sport in which many high-intensity short-time actions occur: sprints, turning, throwing, blocking, pushing, grabbing, and jumping. These are considered to be the most significant actions to develop high performance (Bilge, 2013; Michalsik et al., 2013; Karcher & Buchheit, 2014; Iacono et al., 2015b). In their study on professional handball players, Povoas et al. (2012) showed how athletes performed very short 825 actions (2-6 seconds) in a 73-minute game, investing a lot of energy in acceleration and deceleration. Stops and changes in direction were the most repeated actions in the game. 80% of game time, players performed low-intensity aerobic actions (Povoas et al., 2012). This proved the intermittent profile of this sport, as in other collective sports, as well as how important it is to develop good aerobic and anaerobic systems to increase performance (Paludo et al., 2008).

High-intensity interval training (HIIT) is considered optimal workout to improve both metabolic and cardiovascular functions in athletes (Buchheit & Laursen, 2013; Foster et al., 2015), even without previous experience (Alonso-Fernandez et al., 2017). As opposed to steady-pace and continuous training, interval training builds up more high-intensity stimuli, closer to collective sports requirements, such as in those in handball (Dupont et al., 2003; Buchheit et al., 2007; Buchheit & Laursen, 2013). HIIT therefore becomes a good time-efficient strategy to spur in training adaptation similar to competition (Burgomaster et al., 2005; Martins et al., 2016). The effectiveness of this method lies in the possibility to target and monitor workload thanks to various reference tests (Wong et al., 2009; Buchheit et al, 2009). Interval training is based on 5 variables: intensity and length of work-time, intensity and length of rest-time, and training total volume (Bilge, 2013). HIIT can be classified according to the length of work intervals: long HIIT (3-15 min), moderate (1-3 min) or short (10s-1 min) (Guiraud et al., 2012).

Despite HIIT potential in team sports, there are few studies on the implementation of HIIT in handball players' preparation. Rey et al. (2017) have recently conducted a study on this sport in which two different HIIT typologies were compared, based on the use of running and the length of the work interval (long and short). Improvements on V02max and Repeat Sprint Ability (RSA) were obtained in both groups after 6 weeks of training.

To this day, no study has been made on the impact of HIIT based on functional exercises adapted to handball. Therefore, the aim of this study is to measure the impact of 8 weeks of HIIT based on functional training on female players, measuring various variables with an impact on sports performance: jumping, RSA, Vo2max, and body composition (weight, BMI, % fat).

MATERIALS AND METHODS

This study applied an experiment design based on the random allocation of players to two groups: an experimental group (GE), which would undergo HIIT before the usual training in handball. In order to determine the effects of the training protocol the following tests were selected: (a) countermovement jump (CMJ), (b) repeated sprint ability (RSA), (c) aerobic capacity test 20m-SRT y (d) bioelectric bioimpedance analysis of body composition.

Participants

Fourteen female players of the Club Balonmano Atlético Guardés (15.2±0.6 years old) took part in the study. All of them had been doing sport for at least 5 years, but none of them had done HIIT. The requirement for selection was the commitment to follow the whole protocol. Players who had suffered an injury forcing them

to stop playing or training for over two weeks in the two months previous to the study were excluded. Participants were informed of the purpose of the study, as well as of risks and benefits. All participants gave an informed consent for voluntary participation, signed by their legal tutors as participants were underage. In addition, they were instructed to keep usual food and rest habits during the study in order to better isolate the effects of the proposed training. Anthropometric features of the sample are shown in Table 1.

Table 1. Anthropometric features of the sample.

	GE (n=7)	GC (n=7)
Height (m)	1.64 ± 0.05	1.66 ± 9.24
Weight (Kg)	63.17 ± 9.44	67.29 ± 0.03
BMI (kg)	23.83 ± 3.46	24.61 ± 3.93
% fat	30.13 ± 4.16	32.00 ± 5.24

Given the protocol and techniques applied, this study respected all ethical procedures for data collection and relevant legislation in force (*Ley orgánica 15/1999, sobre protección de datos de carácter personal*). This research complied with the Helsinki Declaration.

Procedure

The study was conducted in the second half of the 2016-2017 season, between January and March. The programme lasted for 8 weeks, with two non-consecutive training sessions a week conducted before the usual training sessions. The GE had 16 sessions of HIIT based on functional exercises. The GC replaced HIIT with usual handball warm-up sessions. In order to isolate HIIT impact as much as possible, both groups had the main handball training sessions together at the same time.

The players underwent a pre-test and post-test before and after the 8-week training. For each test, measures were taken in two days. In order to reduce measure variability to the minimum, the same protocol was followed. Participants could not have caffeinated or alcoholic drinks nor have any kind of food in the three hours prior to the test.

The pre-test included the following tests in the first day:

Body composition: biometric bioimpedence analysis was used (Tanita BC-601, Tanita Corp., Tokio, Japón). Three measures were taken on the equipment to obtain the weighted average value of the following variables: weight (kg), body mass index (BMI), and % fat.

Countermovement jump (CMJ): assessed through the mobile app "*My Jump 2*" (Balsalobre y Glaiser, 2015), measuring the following variables: height (cm), flight time (ms), speed (m/s), strength (N) y power (W). The intra-class correlation coefficient (ICC) in test-retest trials was 0.96 (95% confidence interval (CI) 0.92-0.97).

RSA: the 4-linear sprints with change in direction standardised test was conducted (Rosch et al., 2000). Test time was measure by a photoelectric cell system (DSD Laser system). Participants had to use the same shoes in both test sessions to minimise variability between the tests. ICCs in test-retest trials were 0.96 (95% CI 0.90-0.97).

In the second day of pre-test, the following items were measured:

VO2max predictive field test: incremental acceleration and deceleration test up to exhaustion. Run both ways between two lines 20 metres apart (20m-SRT) (Léger et al., 1984). Results will help us reliably predict participants' VO2max (García & Secchi, 2014).

HIT*T training protocol*

The HIIT implemented was based on the "Tabata" method (Tabata et al., 1996). It includes 4-minute work blocks with 8 20-second intensive-work periods followed by 10-second rest periods. As participant players did not have previous experience in HIIT, workload increased gradually (Table 2). Intensity was monitored through pulse meters (Polar T2, Polar Electro Oy, Kempele, Finland), always above 85%. Exercise internal workload and intensity were measured rating the perceived effort (RPE) on a Foster 0-10 scale (Foster et al., 2001).

Table 2. Progress in mixed functional HIIT over 8 weeks.

	Training volume	
Week	Work/rest time per session	Total work and rest time
1	4´	Work time: 4´ Rest time:0´
2	4´	Work time:4´ Rest time:0´
3	4´/2´/4´	Work time:8´ Rest time:2´
4	4´/2´/4´	Work time:8´ Rest time:2´
5	4´/2´/4´/2´/4´	Work time:12´ Rest time:4´
6	4´/2´/4´/2´/4´	Work time:12´ Rest time:4´
7	4´/2´/4´/2´/4´/2´/4´	Work time:16´ Rest time:6´
8	4´2´/4´/2´/4´/2´/4´	Work time:16´ Rest time:8´

Before each HIIT session, GE players had a standardised warm-up 10-minute session including 4 minutes of general warm-up plus 6 minutes of specific warm-up (Table 3). GC players had a standard handball warm-up session. After their respective sessions, both groups (GE y GC) had a joint handball training session designed by the technical team.

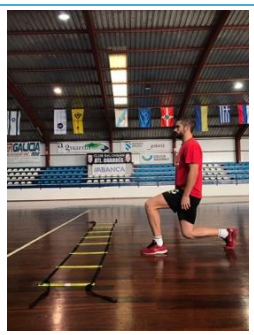
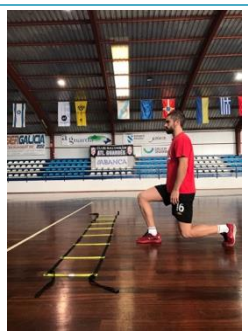
Table 3. Organisation and content of GE warm-up session.

Time	Content
4 min	Static joint mobility
6 min	Running with dynamic joint mobility Calisthenics exercises: • Squats. • Isometric plank moves. Low-impact strength, coordination and plyometric exercises: • Rubber-band chest press. • TRX squat. • Front plank with support variation. • Static split. • Simple coordination exercise on ladder. • Bridge. • Jumping into and out of a hoop with both feet together.

Functional strength, coordination and plyometric exercises were selected for the training protocol, all of them adapted to handball. The protocol was called "Mixed functional HIIT". The purpose of the training is to prepare athletes for functional actions linked to changing actions usually performed in handball (Table 4). The following features were taken into account in order to select the exercises: (a) for exercises not to require specialised equipment, so that they could be done in any club and with any number of players (b) simple technical execution, as high-intensity actions undermine fine-grained technical control.

Table 4. Selected exercises for mixed functional HIIT.

Week 1 sessions		
Name of the exercise		
	START	**END**
Squat and jump		

Dynamic split with both legs		
Mountain Climbers		
Coordination exercise on ladder		
Week 2 sessions		
Name of the exercise		
	START	**END**
Plyometric jumps		

Squat		
Upper-body plyometric exercise		
Coordination exercise on ladder		

Data analysis

Normal data distribution was verified through a Shapiro-Wilk test. Homoscedasticity was measured through a Levene test. Changes over time in dependent variables were compared between groups through repeated measures ANOVA test (2groups x 2 time points: pre-test and posy-test). A Tukey post-hoc test was run to establish significant differences between pairwise comparisons. A $P<.05$ was established. When necessary, Cohen´s d was included to measure impact, where 0.2, 0.5 y 0.8 represent small, medium and big differences (Cohen, 1988). In addition, percentage differences between pre- and post-test were calculated for both groups. All the analyses were done with SPSS 25.0 for MacOs (IBM Corporation, Chicago, IL).

RESULTS

RPE was taken over the 8 weeks of training, with values between 6 and 9 (Figure 1).

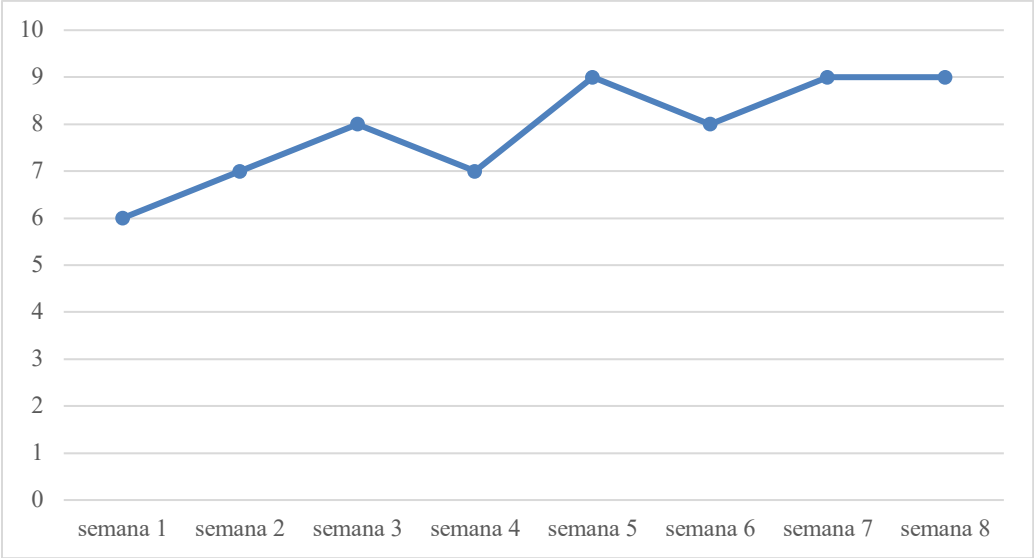


*Figure 1. RPE values over 8 weeks of mixed functional HIIT in the GE (*semana=*week)*

After the intervention programme, the GC didn't show significant changes in any of the studied variables. The GE, however, showed significant differences in body composition, specifically in players' % fat, with a significant reduction by 3.45% (*d* = 0.67). Furthermore, the GE's RSA execution time decreased by 7.22% (d = 0.82); VO2max increased by 6.19% (d = 0.78). No significant changes in weight, BMI and CMJ were found. All values are shown in Table 5 below.

Table 5. Changes in body composition, CMJ, RSA and VO2max GE and GC (average ± SD).

	GE (experimental group) (n=7)			***GC (control group) (n=7)***		
Variables	***Pre-test***	***Post-test***	***% Change***	***Pre-test***	***Post-test***	***% Change***
Weight (kg)	63.17 ± 9.44	63 ± 7.81	-0.27	67.29 ± 9.24	67.11 ± 8.46	-0.27
BMI	23.83± 3.46	23.71 ± 2.34	-0.5	24.95 ± 3.93	24.5 ± 4.17	-1.8
Body fat (%)	30.13 ± 4.16	**29.09 ± 3.59***	-3.45	32 ± 5.24	31.6 ± 4.99	-1.25
Jump (CMJ)						
Height (cm)	29.39 ± 1.60	30.76 ± 3.53	4.66	28.15 ± 3.46	28.26 ± 3.06	0.39
Flight time (ms)	489.43 ± 13.19	500.29 ± 29.55	2.22	479.29 ± 29.67	478.57 ± 24.64	-0.15
Speed (m/s)	1.20 ± 0.03	1.23 ± 0.07	2.5	1.17 ± 0.08	1.17 ± 0.07	0
Strength (N)	1642.88 ± 343.31	1672.77 ± 248.48	1.82	1672.95 ± 258.38	1735.15 ± 278.30	3.72
Power (W)	1973.67 ± 416.47	2055.85 ± 346.58	4.16	1958 ± 326.48	2017.98 ± 283.85	3.06
RSA (s)	16.76 ± 0,72	**15.55 ± 0.55***	-7.22	17.74 ± 1.24	17.46 ± 1.31	-1.58
VO2max (ml/kg/min)	43.96 ± 2.8	**46.68 ± 2.60***	6.19	42.73 ± 6.53	43.27 ± 6.31	1.26

** = P < .05 vs pre-test*

DISCUSSION

This is the first study conducted with a controlled design and specific field tests aiming at assessing the effectiveness of an 8-week HIIT mixed programme based on functional exercises. Several variables were measured to assess the impact of that HIIT programme on female handball players: body composition, jump (CMJ), RSA and Vo2max. The main outcomes of this study were as follows: HIIT training led to (a) a reduction in player's % fat, (b) an improvement in RSA performance and (c) better VO2max values.

The outcomes of this study show that mixed functional HIIT is a valid strategy to reduce the % fat and to improve body composition in female handball players. These results are in line to those obtained by Balbasi et al. (2016), who after a 3-week HIIT programme with young indoor football players saw a significant reduction in % body fat. Nevertheless, authors such as Camacho-Cardenosa et al. (2016) did not detect significant improvements in this variable in a study conducted with non-athlete teenagers who underwent an 8-week HIIT protocol. Considering that calorie intake and food monitoring have a significant impact on this variable, it is safe to assume that more regular and stable food habits in sportspeople may increase HIIT impact on % body fat.

Optimal performances in handball requires a high amount of explosive actions such as sprints, jumps and changes in direction during the game (Karcher & Buchheit, 2014). In our study, no significant differences have been found regarding variables involved in CMJ, in line with results obtained by Buchheit et al. (2009) with young handball players, in which CMJ did not either develop after HIIT. More recently, Rey et al. (2017) apply two types of HIIT protocol (long and short) to a sample of handball players during 6 weeks, again with no improvement on CMJ. However, these data are opposed to results achieved by Iacono et al. (2015a) with handball players. After 8 weeks of small-sided games and HIIT significant improvement was shown in CMJ in both groups. Stimuli in our study may not have been enough to stimulate the neuromuscular system linked to the production of explosive strength. A higher number of specific functional exercises in the HIIT programme implemented, such as plyometric exercises, will probably lead to improvements in CMJ. This may be a strategy to bear in mind in future studies.

A major outcome in our study is RSA development. It is a key element for performance in handball, given that players need to repeat intermittent sprints with multidirectional changes, interspersed with very short rest periods (Povoas et al., 2012). That is why training strategies on this ability may lead to improvements in players' performance in handball (Rey et al, 2017). Results show that after 8 weeks of mixed functional HIIT, GE players showed a significant increase in RSA. These results are consistent with those obtained by Rey et al. (2017). Better results in RSA may probably draw on parallel improvements in aerobic capacity (Buchheit et al., 2010), thanks to less accumulation and better elimination of lactic acid between sprints (Jódar, 2003).

In addition, a significant 6.19% increase in V02max was achieved. Similar results were recorded by Buchheit et al. (2009), with a 7% improvement in VO2max values applying a HIIT protocol to young handball players twice a week. Given the need to work on a large quantity of physical, technical, and tactical elements during weekly sessions, HIIT could be a good strategy to improve aerobic performance in players, thanks to its limited volume, allowing for more time for working on other elements. Training exercises must be adapted to the sport specific features, such as game duration, percentage of heart rate, work and rate times, effort profiles, running distance, and specific features associated with players' roles and positions in the team (Bilge, 2013).

Nonetheless, the authors are aware that the interpretation of the results obtained in this study may be limited by the fact of not having players in the top category as participants. It would be advisable to conduct similar studies on professional players to verify if HIIT may also be an option in their training.

CONCLUSIONS

Mixed functional HIIT has proved to be an effective method to improve values in body composition, RSA y VO2max in a simple of handball players. In practical terms, the most relevant conclusion is that this type of work seems to be a valid strategy to be included in plans devised by coaches and physical trainers for their teams. HIIT would therefore seem a promising method to be applied in collective sports, as it can be adapted to specific needs of player training. HIIT limited volume, and the possibility to include diverse exercises and tasks, make it a sound method to bear in mind for the specific development of physical abilities in handball training.

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