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Cardiopulmonary- versus neuromuscular-based high-intensity interval training during a pre-season in youth female basketball players

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ABSTRACT
Purpose. This study compares the effects of 6 weeks of pre-season cardiopulmonary- vs. neuromuscular-based high-intensity interval training (HIIT) in female basketball players' physical fitness.
Methods. Overall, 16 female regional-level U19 basketball players were randomly allocated to a cardiopulmonary-based HIIT (C-HIIT) group (n = 8; age: 17.9 ± 0.6 years; height: 175.4 ± 6.5 cm; body mass: 68.1 ± 7.2 kg) or a neuromuscular-based HIIT (N-HIIT) group (n = 8; age: 18.0 ± 0.4 years; height: 175.6 ± 3.6 cm; body mass: 69.8 ± 5.0 kg). At the PRE-, MID- (3 weeks), and POST-training time points, the participants performed a 30-15 Intermittent Fitness Test (30-15 IFT; aerobic performance) and a repeated sprint ability (RSA) test (6 × 15 + 15 m [with 180° change of direction] with 20-second passive recovery).
Results. A 2 × 3 mixed model analysis of variance revealed that both training interventions improved (p < 0.05) 30-15 IFT after 6 weeks (C-HIIT, 8.6% and ES = 2.01; N-HIIT, 3.3% and ES = 0.52). C-HIIT improved (p < 0.05) 30-15 IFT after 3 weeks (3.8%, ES = 0.90). Neither group improved (p > 0.05) in RSA results.
Conclusions. C-HIIT and N-HIIT improves aerobic performance in female basketball players. However, for improvements in RSA, other training drills (e.g., repeated sprint training) and tasks with a higher number of changes of direction may be investigated.
Key words: women, sport, cardiorespiratory fitness, physical fitness

Introduction

Female basket players perform linear sprints (57% performed over 1–5 m; 30% over 6–10 m) every 33 seconds, mostly without the ball [1], and a considerably high number of high-intensity actions (35 ± 11 jumps, 49 ± 17 sprints, and 58 ± 19 high-intensity shuffles) [2] during a match. Thus, the ability to undertake high-intensity efforts, particularly repeated sprints, is a significant component of elite female basketball. Older [3] and high competitive level [4] team sports players show better repeated sprint performance. In addition, athletes with better repeated sprint performance present higher physical performance in soccer [5] and rugby [4], and those with better developed repeated sprint ability (RSA) performed more high-speed running per minute of match play than individuals with poorly developed RSA [6]. Fort-Vanmeerhaeghe et al. [7] did not show differences in performance as a function of age in female basketball players, possibly be-

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cause they compared players of similar age (U16 vs. U18) and similar weekly training load.

RSA is a complex quality that has been associated with both neuromuscular (e.g., peak locomotor speed, neural drive, and motor unit activation) and metabolic factors (e.g., oxidative capacity, phosphocreatine recovery, and H^+ buffering) [8]. In addition, RSA reflects the ability of a young female basketball player to recover and sustain maximal or near-maximal efforts during subsequent running sprints [9]. Small-sided games (e.g., 2v2 28 × 7.5 m twice a week during 6 weeks) [10], basketball-specific high-intensity interval training (HIIT) (e.g., 4 × 4 minutes with 3-minute recovery and 15 × 30-second high-intensity basketball drills involving fundamental skills, such as dribbling, passing, and shooting) [11], and running-based HIIT (e.g., 2 × 8–13 minutes, 15 seconds at 95% of Intermittent Fitness Test [IFT] velocity [VIFT] with 15-second recovery) [12] have been evaluated in order to improve RSA in young basketball players. There is evidence showing performance improvements in the RSA test in young basketball players after a 5-week training program consisting of repeated 30-m sprints [13], but not after small-sided games or HIIT [10]. However, Delextrat et al. [12] observed that HIIT allowed to improve repeated sprint performance in young basketball players.

Improvements in RSA best time after repeated sprint training and intermittent training have been obtained in young female basketball players, with a further increase in performance for intermittent training compared with repeated sprint training (6.2% vs. 3.1%) [9]. Therefore, HIIT seems to be a useful strategy in improving physical performance in female basketball players.

HIIT has been advocated as a sport-specific conditioning strategy since it allows to mimic sport-specific competition demands and is a time-efficient way to improve aerobic performance (VO_2max) in young female basketball players [11]. VO_2max estimated from the Yo-Yo Intermittent Recovery (IR) test is the physical fitness variable which describes, at the highest level (t = 9.32), the match performance index (calculated on the basis of the various parameters of situational performance) [14]. The distribution of load and recovery during HIIT allows to accumulate greater volume of intense training (elicit VO_2max, or at least a very high percentage of VO_2max, maximally stress the oxygen transport and utilization systems) with reduced fatigue-related effects [15]. Running speed individualization for basketball players engaged in HIIT has been defined in previous research [10, 12] by using values of end speed obtained for 30-15 IFT [16]. The end speed obtained in 30-15 IFT has been suggested as a workload indicator that allows to expose players with different physiological profiles to a similar level of cardiorespiratory demand and that reflects, in addition to maximal cardiorespiratory function, the anaerobic capacity and neuromuscular qualities [17].

Prescription of HIIT involves the manipulation of up to 9 variables, very important being the intensity, the number of series, or the workload modality, since they have a direct effect on the acute physiological responses to HIIT and allow to orient training towards cardiopulmonary (eliciting essentially large requirements from the O_2 transport and utilization systems, i.e., oxidative muscle fibre) [15] or neuromuscular (important anaerobic glycolytic energy contribution and a large neuromuscular load) [18] adaptations. Although HIIT has been compared with other interventions, such as small-sided games [12] and 1 or 3 changes of direction (COD) [19] in female basketball players, there are no studies comparing the effects of cardiopulmonary-based HIIT (C-HIIT) and neuromuscular-based HIIT (N-HIIT). Therefore, the aim of this study was to investigate the effects of 6 weeks of pre-season C-HIIT vs. N-HIIT in female basketball players. We hypothesized that N-HIIT would improve RSA, whereas C-HIIT would improve aerobic performance.

Material and methods

Study design

The current study involved a randomized parallel matched-group design with repeated measures, including a pre-intervention assessment, intervention period, and post-intervention assessment. To examine the effect of 6-week (2 training sessions per week) C-HIIT vs. N-HIIT on RSA and aerobic performance, 16 U19 female basketball players were randomly allocated to a C-HIIT (n = 8) or N-HIIT (n = 8) training group. The subjects were recruited from 2 different teams. Both teams presented the same competitive level, participated in the same league, and had similar competition schedules and similar basketball training volumes, resulting in comparable basketball-specific weekly training loads in the last season prior to the present study. An RSA test and 30-15 IFT were performed before, during (i.e., at 3 weeks), and after the HIIT intervention (i.e., at 6 weeks). The individuals were familiarized with the testing procedures during 2 separate sessions (30–45-minute familiarization in each) prior to the study onset. After the familiarization period, the athletes performed the RSA test in session 1 and the 30-15 IFT in session 2, with a 24-hour recovery between the sessions. Standardized warm-up (5 minutes of low-intensity running and mobility, 5 minutes of submaximal running with COD, and 5 × 10-m run sprint) was carried out before each testing session. In the post-training assessment sessions, all tests were performed ≥ 72 hours after the last training session. All tests were implemented in a controlled indoor environment, at the same time of the day (between 18:00 and 20:00 hours). The HIIT intervention was applied over 6 weeks in the pre-season, which is in line with the recommended duration for aerobic performance adaptations [20] and the usual duration of pre-season in basketball.

Subjects

A total of 16 female regional-level U19 basketball players volunteered to participate in this study and were selected on the basis of the following inclusion criteria: (i) a background of ≥ 5 years of systematic basketball training and competitive experience, (ii) absence of potential medical problems, and (iii) absence of any lower-extremity surgery in the previous 2 years. The participants were required to attend ≥ 80% of all training sessions (C-HIIT or N-HIIT) and all assessment sessions. The athletes of both teams who fulfilled the inclusion criteria were randomly assigned (single-blinded; https://www.randomizer.org) to C-HIIT (age: 17.9 ± 0.6 years; height: 175.4 ± 6.5 cm; body mass: 68.1 ± 7.2 kg) or N-HIIT (age: 18.0 ± 0.4 years; height: 175.6 ± 3.6 cm; body mass: 69.8 ± 5.0 kg) groups. During the 3 months prior to the start of the study, both groups performed 3 weekly training sessions (90 minutes per training session) and 1 official match.

Procedures

Aerobic performance

The 30-15 IFT was conducted as previously detailed in basketball players [12]. It is characterized by very good test-retest reliability [21]. The test consists of 30-second shuttle runs interspersed with 15-second passive recovery periods. The initial running velocity was set at 8 km · h^{-1} for the first 30-second stage, and the speed was increased by 0.5 km · h^{-1} every 30 seconds thereafter. The subjects were instructed to complete as many stages as possible, and the test ended when the player could no longer maintain the required running speed (did not reach the beep zone on 3 consecutive occasions). The speed attained in the last fully completed stage (VIFT, km · h^{-1}) was recorded to estimate maximal aerobic performance and to prescribe HIIT.

Repeated sprint ability

The participants completed a 6 × 15 + 15-m COD (180°) sprint, with 20-second passive recovery between sprints, similar to that reported in previous studies [10]. To ensure maximal effort during testing, the athletes completed a 15 + 15-m COD (180°) maximal sprint, which provided a criterion score before RSA testing [22]. If the first sprint of the RSA test was 2.5% worse than the criterion score, the test was terminated and resumed after 5 minutes of recovery. The starting position was 0.5 m behind the first timing gate (DSD Laser System®, Sport Test software, v. 3.2.1, Spain). The players were strongly motivated via verbal encouragement to exert maximal effort during testing. The best time (RSA_b), mean time (RSA_m), total time (RSA_t), and decrement (RSA_{Sdec}) were registered for further analysis.

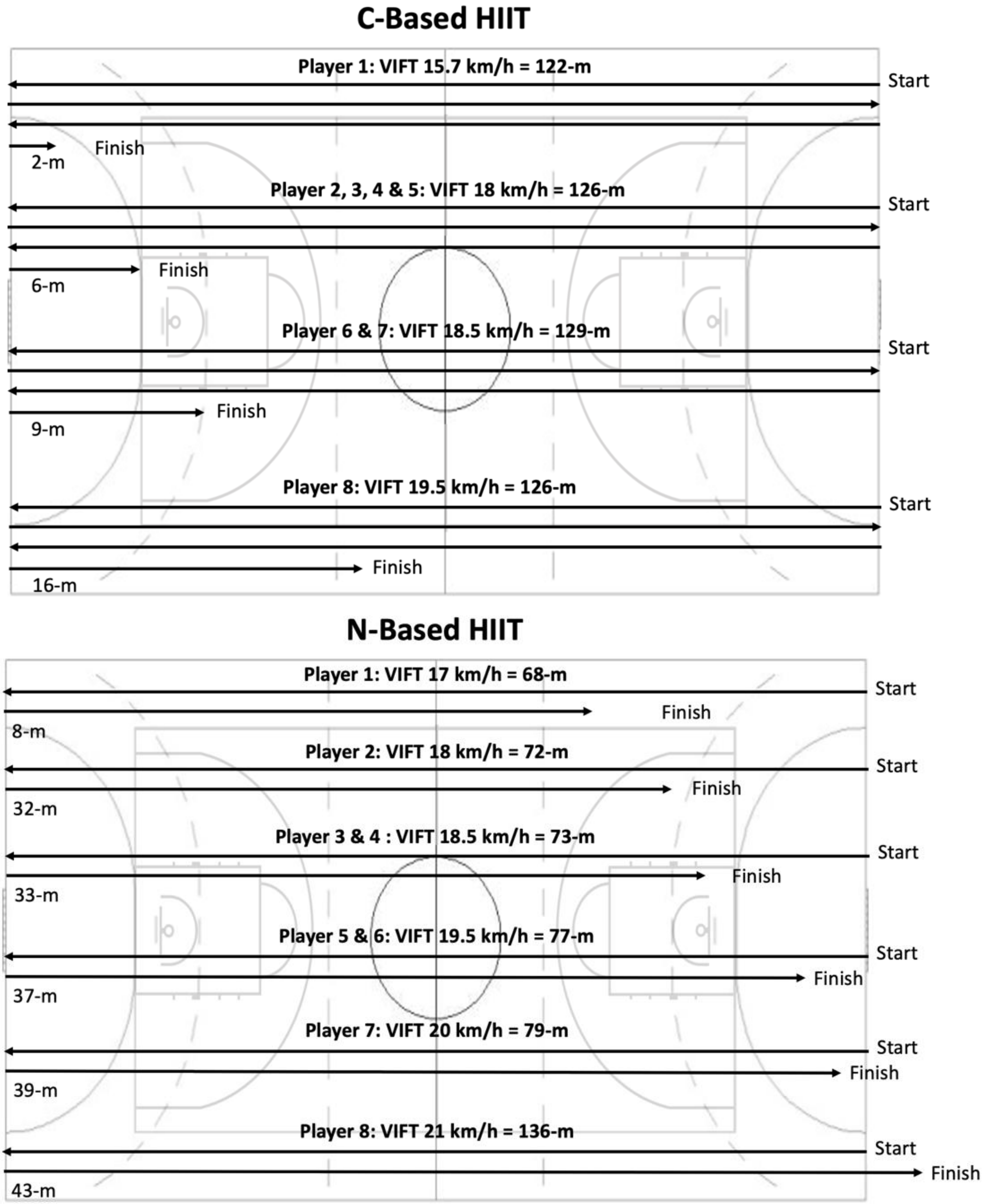
Training program

Both HIIT protocols were performed twice per week (Tuesday and Friday), for 6 weeks, in addition to the participants' regular training schedule. An Excel file (Spreadsheet for Interval Training prescription, https://30-15ift.com/downloads/) was used to design each HIIT protocol. After a 15-minute warm-up (low-intensity running, dynamic stretching, and specific drill), the players performed C-HIIT (30 seconds of running at 90% VIFT and 30 seconds of passive recovery) or N-HIIT (15 seconds of running at 100% VIFT and 15 seconds of passive recovery) (Table 1).

Table 1. High-intensity interval training protocols for the cardiopulmonary-based group and the neuromuscular-based group

Training program	Running / recovery (type) time	VIFT	Shuttle length	Number × duration (recovery time) of sets
C-HIIT	30 s / 30 s (passive)	90%	40 m	2 × 12 min (3 min)
N-HIIT	15 s / 15 s (passive)	100%	40 m	2 × 6 min (6 min)

C-HIIT – cardiopulmonary-based high-intensity interval training, N-HIIT – neuromuscular-based high-intensity interval training, VIFT – velocity registered at the end of the 30-15 Intermittent Fitness Test



C-based – cardiopulmonary-based, N-based – neuromuscular-based
HIIT – high-intensity interval training, VIFT – velocity registered at the end of the 30-15 Intermittent Fitness Test

Figure 1. High-intensity interval training circuits in the cardiopulmonary-based group and the neuromuscular-based group

Both groups performed a shuttle of 40 m, with 3 COD (180°) for C-HIIT and 1 COD (180°) for N-HIIT, whereas the total distance covered by each player depended on VIFT and the type of intervention (Figure 1). To adjust the speed to individual intensity, the subjects had to adapt their speed to the acoustic signal (Sony ENG203® speaker, Tokyo, Japan) that indicated the start, finish, and recovery time.

Statistical analyses

Data are presented as group mean values ± 95% confidence intervals. All data were assessed for normal distribution with the Kolmogorov-Smirnov test. A 2 × 3 mixed model analysis of variance (ANOVA) was used to investigate differences between the groups for all performance variables (RSA and VIFT), with time (PRE-, MID-, and POST-training) as an intra-subject factor and group (C-HIIT vs. N-HIIT) as an inter-subject factor. The Greenhouse-Geisser correction was applied when the assumption of sphericity was violated. When a significant time × group interaction was found, Bonferroni-corrected post-hoc tests were conducted to determine statistically significant pairwise comparisons. Effect sizes (Cohen's d_{av} [23]) were also calculated, and values of > 0.8, 0.5–0.8, 0.2–0.5, and < 0.2 were considered as large, moderate, small, and trivial, respectively [24]. Further, ANOVA effect sizes were determined with partial eta squared (η_p^2), and values of < 0.25, 0.26–0.63, and > 0.63 were considered as small, medium, and large effect sizes, respectively [25]. The significance of the results was assumed at $p < 0.05$. All analyses were performed by using SPSS software, version 21.0 (IBM Corp., released 2012, IBM SPSS Statistics for Windows, version 21.0, Armonk, NY, USA).

Ethical approval

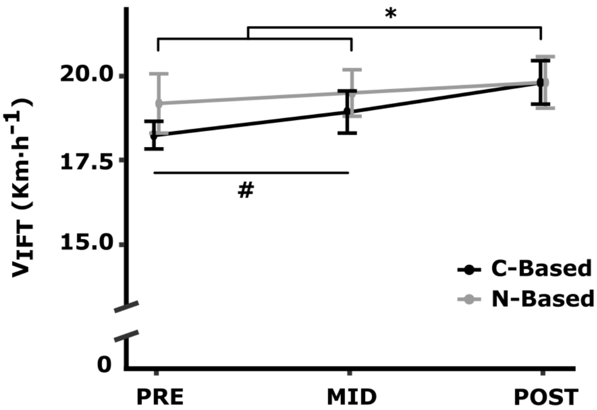
The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Ethics Committee of University of León (approval No.: ETICA-ULE-004-2021).

Informed consent

Informed consent has been obtained from all individuals included in this study and, for players under 18 years of age, from their legal guardians.

Results

A group × time interaction was revealed for VIFT ($p < 0.001$; $\eta_p^2 = 0.55$; Figure 2), along with a significant time effect ($p < 0.001$; $\eta_p^2 = 0.87$), whereas no significant main effect was observed for group ($p = 0.32$; $\eta_p^2 = 0.07$). Post-hoc pairwise comparisons indicated that both the C-HIIT and the N-HIIT group showed larger POST-training VIFT values when compared with PRE- (8.56%, *ES* = 2.01; and 3.26%, *ES* = 0.52, respectively) and MID-training ones (4.62%, *ES* = 0.95; and 1.60%, *ES* = 0.29, respectively), whereas only the C-HIIT group exhibited larger VIFT values at the MID-training time point compared with the PRE-training one (3.8%, *ES* = 0.90).



C-based – cardiopulmonary-based
N-based – neuromuscular-based
* $p < 0.001$ for PRE-POST and MID-POST comparisons, for both C-based and N-based groups, # $p < 0.01$ for PRE-MID comparison only for C-based group

Figure 2. Velocity in the Intermittent Fitness Test (VIFT) assessed at PRE-, MID-, and POST-training tests for C-based and N-based high-intensity interval training groups

A summary of the results obtained when performing the 2 × 3 mixed model ANOVA for RSA_b, RSA_m, RSA_t, and RSA_{Sdec} is shown in Table 2. No significant time × group interaction was found for RSA_b ($p = 0.61$; $\eta_p^2 = 0.03$), RSA_m ($p = 0.54$; $\eta_p^2 = 0.03$), RSA_t ($p = 0.54$; $\eta_p^2 = 0.04$), or RSA_{Sdec} ($p = 0.33$; $\eta_p^2 = 0.07$). Also, no main effects were observed for the independent analysis of time and group factors ($p > 0.05$ for all variables).

Discussion

The aim of this study was to compare the effects of 6 weeks of pre-season C-HIIT vs. N-HIIT in female basketball players. HIIT is an alternative training modality to more traditional continuous low-intensity run-

Table 2. Repeated sprint ability measures at the PRE-, MID-, and POST-training time points in C-based and N-based HIIT groups

Measure	HIIT type	PRE	MID	POST	*ES*		
					PRE-MID	PRE-POST	MID-POST
RSA_t (s)	C-based	35.27 (34.68–35.86)	35.3 (34.04–36.55)	35.05 (34.50–35.59)	0.03*	0.32	0.22
	N-based	34.77 (34.13–35.40)	34.43 (33.75–35.12)	34.43 (34.10–34.76)	0.43	0.56	0.00*
RSA_b (s)	C-based	5.72 (5.62–5.81)	5.67 (5.55–5.79)	5.68 (5.59–5.78)	0.40	0.37	0.08
	N-based	5.68 (5.61–5.75)	5.64 (5.52–5.76)	5.62 (5.55–5.69)	0.35	0.66	0.18
RSA_m (s)	C-based	5.88 (34.68–35.86)	5.89 (34.04–36.55)	5.84 (34.50–35.59)	0.05*	0.35	0.26
	N-based	5.80 (34.13–35.4)	5.74 (33.75–35.12)	5.74 (34.10–34.76)	0.45	0.58	0.00*
RSA_{Sdec} (%)	C-based	2.80 (2.35–3.25)	3.77 (1.14–6.39)	2.77 (1.85–3.69)	0.43	0.03*	0.42
	N-based	2.05 (1.34–2.76)	1.83 (1.38–2.28)	2.17 (1.23–3.12)	0.31	0.12	0.38

Values are represented as mean (95% confidence interval).
HIIT – high-intensity interval training, C-based – cardiopulmonary-based, N-based – neuromuscular-based, *ES* – effect size, RSA – repeated sprint ability, RSA_t – total time in RSA test, RSA_b – best time in RSA test, RSA_m – mean time in RSA test, RSA_{Sdec} – decrement in RSA test
* statistically significant values

ning protocols for improving aerobic fitness in team sport players [15, 18]. However, while previous studies compared the effects of HIIT vs. other training strategies, such as small-sided games [12] or HIIT with 1 or 3 COD [19], in female basketball players, the present study is the first to investigate the effect of 2 types of HIIT (i.e., C-HIIT vs. N-HIIT). The main results show that C-HIIT and N-HIIT improved aerobic performance (i.e., 30-15 VIFT) after 6 weeks (8.5% and 3.3%, respectively), but only C-HIIT significantly improved (3.8%) performance after 3 weeks. Neither group significantly improved RSA performance, although after 6 weeks the N-HIIT group exhibited an effect size of 0.56, 0.66, and 0.58 for RSA_t, RSA_b, and RSA_m, respectively.

A previous study presented improvements (ca. 26%, very likely) in aerobic performance determined by the Yo-Yo IR level 1 test after applying HIIT in youth female basketball players, although the improvement was not statistically significant ($p = 0.13$; $ES = 1.13$) [11]. A similar finding was noted in female volleyball players (18.3%) [26]. In this regard, Delextrat and Martinez [10] reported no significant time × group interaction ($p = 0.765$; $\eta^2 = 0.006$) after 6 weeks of small-sided games (ca. 3.5%) or HIIT (ca. 4%) for VIFT among female basketball players. In contrast, the current results indicate a significant improvement (time × group: $p < 0.001$; $\eta_p^2 = 0.55$) in VIFT after 6 weeks for both C-HIIT (8.5%) and N-HIIT (3.3%). Given that pre-season is a sensitive time to increase aerobic performance [27], differences in results between studies may be due to the fact that the present study was carried out in pre-season, whereas Aschendorf et al. [11] and Delextrat and Martinez [10] analysed the effects of HIIT during the competitive season. Furthermore, the intensity in our study was individualized for each player, unlike in the research by Aschendorf et al. [11].

With regard to our hypothesis, both C-HIIT ($p < 0.001$; $ES = 2.01$) and N-HIIT ($p < 0.001$; $ES = 0.52$) significantly improved VIFT after 6 weeks. However, C-HIIT also improved VIFT after 3 weeks ($p < 0.01$; $ES = 0.95$). Although VIFT is determined by aerobic and anaerobic metabolism [16], its large correlations with VO_2max ($r = 0.67$; $p = 0.012$) [28] and Yo-Yo IR level 1 distance ($r = 0.71$; $p = 0.003$) [29] in female athletes denote that the improvements in our study might eminently reflect cardiovascular adaptations. The obtained improvements are of crucial relevance since the VO_2max estimated from a field test (Yo-Yo IR) has been shown to predict performance in young basketball players [14].

Given the significance of RSA for basketball performance [12], interest has been taken in the implementation of training protocols leading to RSA improvement in basketball players. Contrary to our hypothesis, N-HIIT and C-HIIT (both involving COD movements) did not increase RSA performance. These results are in line with previous research reporting no increase in either RSA_b or RSA_m in young female basketball players after developing a HIIT COD protocol for 6 weeks, twice per week [19]. Moreover, Delextrat and Martinez [10] and Delextrat et al. [12] reported no RSA improvements after a HIIT protocol consisting of 15-second running at 95% of players' VIFT, followed by 15-second active recovery. However, Sanchez-Sanchez et al. [19] observed improved RSA_m (3.3%, possibly) when the number of COD performed during HIIT was increased (1 vs. 3 COD); this suggests that a greater number of accelerations and decelerations leads to more sound neuromuscular factors relevant to RSA performance [30]. Since participants from the N-HIIT group performed only 1 COD, whereas the C-HIIT group performed 3 COD (see Figure 1), it might be argued that RSA benefits resulting from N-HIIT COD may have been disguised by between-group differences in the number of performed COD. Thus, future research is needed to evaluate whether the lack of effect of the N-HIIT protocol on RSA performance observed in the present study was determined by the number of COD applied during training.

Although this is the first study evaluating the effect of C-HIIT and N-HIIT protocols on performance of young female basketball players, it is important to note its limitations. Firstly, we did not include a control condition. However, the aim of this study was to compare 2 different VIFT-based HIIT approaches among 2 equivalent groups of athletes. Nonetheless, future studies might control player training loads (e.g., session rating of perceived exertion) to better account for potential differences between training groups. Secondly, considering the potentially small room for physical performance improvements among highly trained individuals, it might be necessary to conduct studies with larger sample sizes in the future, in order to avoid making type II errors in the null-hypothesis contrast statistical method.

Conclusions

In conclusion, both C-HIIT and N-HIIT may improve aerobic performance (VIFT) after 6 weeks of pre-season training, with C-HIIT inducing even quicker improvements (3 weeks). Our current VIFT-based HIIT approach demonstrated to be effective (for the first time) to improve key physical fitness traits associated with female basketball players' aerobic performance. However, to maximize repeated sprint performance, VIFT-based HIIT may require supplementation with additional training strategies, such as repeated sprint training.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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