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Original Research

Changes in Selected Physiological Parameters Following a Training Block of Specific Circuit Training Among National Top-level Basketball Players

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ABSTRACT

International Journal of Exercise Science 13(6): 1156-1166, 2020. The study aims at measuring the effects of six weeks of specific circuit training (SCT) according to the 15-15 modality, on selected physiological parameters in national top-level basketball players. It was an intervention study, undertaken with 44 senior players randomly assigned to two groups depending on the program: intervention (IG: n = 22; SCT) and control (CG: n = 22; usual content of the defending champion team's), submitted to a six-week training block. The heart rate recovery at 1 (HRR1) and then 2 (HRR2) minutes, the double product (DP) and $\dot{V}O_2max$ were assessed prior to and at the end of the training period. As appropriate, the Student t-test on paired or independent samples, was used to compare measures and groups. At the end of the training period, the HRR1 decreased by 14.2% ($p = 0.01$) and 14.1% ($p = 0.03$) respectively in IG and CG. The mean HRR2 was higher in IG than in GC (63 ± 8 bpm *versus* 57 ± 6 bpm, $p = 0.003$) at the end of the training period. The variation of DP in IG was not significant ($p = 0.42$) while it increased by 7.2% ($p = 0.0005$) in CG. The $\dot{V}O_2max$ increased by 6.5% ($p < 0.001$) in IG but not in CG ($p = 0.50$). The specific circuit training block in the 15-15 modality improved heart rate recovery at one minute and $\dot{V}O_2max$, but had no effect on the double product in the basketball players studied.

KEY WORDS: Technical drills, circuit training, heart recovery index, $\dot{V}O_2max$, double product, basketball

INTRODUCTION

Basketball is an intermittent team sport that lasts four quarters of 10 minutes (17) and requires short but intense actions with incomplete recovery periods. During the game, players cover about 4.5 to 7.5 km in 40 minutes with more than 1000 different actions (frequent starts, jumps, sprints, shots, passes, dribbles, changes of direction, etc.) performed at 85-90% of HRmax (12, 28). The rules, physical and physiological requirements of the match can induce fatigue, causing a drop in the basketball player's performance towards the end of the last quarter. This fatigue can affect grip strength, passing and shooting accuracy in amateur and even professional basketball players (12, 20). A reduction in the intensity of actions at the end of the fourth quarter, as evidenced by lower lactatemia and heart rate than the first, has been noted (28). The ability to repeat intense efforts at the same intensity and with the same effectiveness throughout the game is the key to success in basketball (24). Under these conditions, the ability to recover quickly, whether at cardiac, metabolic or muscular level, will play a decisive role in producing high-level performance during the basketball game, which requires high precision in the execution of technical actions (12). It is therefore necessary to develop ability to repeat intense efforts in players who aspire to higher performance, regardless of their current level.

To improve the ability to repeat short and fast actions and then recover quickly, interval training, which is increasingly used, is one of the reference methods (6). Interval training method has also resulted in weight loss, as well as improved $\dot{V}O_2$max, cardio-respiratory, metabolic and muscular functions (1, 23). Better still in basketball players, interval training has been used to improve technical skills, using specific exercises of dribbling, shooting, passing, etc. (3, 19). When implemented using specific exercises, this method is called a "*specific circuit training*" (SCT), which consists of interval-repeated sequences designed to improve technical skills. The specific circuit training was designed to develop physical abilities and especially to stabilize technical skills, but its effect on the recovery capacity of basketball players has been poorly assessed (2).

Technical skill training, combined with the development of physical and physiological abilities, particularly cardiac recovery during exercise is essential in basketball. Therefore, this study has been undertaken to measure the effects of a six-week training block in the form of a specific circuit training in 15-15 modality (i.e. 15 seconds of high intensity drill and 15 seconds of recovery per cycle of workout) on heart rate recovery indices, double product and $\dot{V}O_2$max, among national top-level basketball players.

METHODS

Participants
The study sample consisted of 44 male senior basketball players, aged 18 to 35 years, including 15 internationals, who have competed in Afrobasket competitions and African Clubs' Championship. All the applied players were sports license holders for the top four elite teams of the 2017-2018 sports season. Participants were randomly assigned to two groups of 22 players each, the intervention group (IG) and one of control (CG). After being informed on the objectives, interest and measures taken to reduce the risks associated with their participation to the research, participants filled out an informed free consent form. Not all the players who were sick two weeks or less before the starting of the study were included in the study sample. Similarly, a player who was absent from more than four of the 18 training sessions and/or absent from one of the measurement sessions should be excluded from the study.

Protocol
This was a controlled interventional study, conducted with senior basketball players who participated in a six-week training block, three times a week during the specific preparation phase of the 2017-2018 sports season. Three days before (M1), then 72 hours after the end of the

training period (M2), different measurements (as resting heart rate (HRr) and blood pressure (BPr)) were taken and all the participants engaged in a physical field test. At each training session, measurements relating to the intensity and workload were taken. All the participants were asked not to engage in any other type of physical exercise during the training period. All the training and the testing procedures were approved by the local University Scientific Committee (003-2017/UAC/INJEPS/CSS-STAPS-JL/SP), conducted according to the ethical principles of Helsinki (30) and standards of the International Journal of Exercise Science (22).

Resting (HRr), exercise mean value (HRe), maximal (HRmax) and recovery (HRrec) heart rate as well as resting blood pressure (BPr) and then on exercise (BPe), were measured respectively, with FT4 (Polar, Finland) heart rate monitor and M6 (Omron, Japan) blood pressure monitors, by people accustomed to the use of such tools. Resting rectal temperature (Trecr) and on exercise (Trece) were measured, using the 10S MT-401R (Thorn, France) automatic thermometers for individual use, with hygiene precautions required (alcohol and cotton). HRmax was assessed during the 30-15 IFT test and HRrec of 1 min and 2 min of post-test recovery. The heart rate recovery (HRR) was calculated using the following formula: HRR = HRmax - HRrec at 1 and then 2 min (7). The double product (DP) was calculated according to the formula: DP (mmHg/min) = (SBP x HRr), SBP as the resting systolic blood pressure (25). The 30-15 IFT test protocol was conducted using a radio-tape recorder and a flash drive containing a pre-recording of the test (8). It is an intermittent field shuttle-run test carried out to assess the maximum aerobic speed (MAS) and $\dot{V}O_2$max. It consists of 30-second running periods interspersed with 15-second recovery periods. During the effort periods, the player runs a shuttle race over a distance of 28 m at a speed indicated by a soundtrack that emits periodic beeps. At recovery periods, the player walks to join the nearest line in front of him, in order to wait for the next departure. A period of race and the subsequent recovery constitute a level (15). The 30-15 IFT for basketball players starts at a speed of 8 km/h, with increments of 0.5 km/h at each level and ends when the player is unable to follow the imposed rhythm. The test was conducted in groups of three or four players. The last level announced is the player's result, which corresponds with his MAS, expressed in km/h and used to estimate maximum oxygen consumption ($\dot{V}O_2$max) in mL/min/kg by using the formula: $\dot{V}O_2$max (mL/min/kg) = 28.3 - 2.15G - 0.741A - 0.0357P - 0.0586A x MAS- 1.03MAS, in which G was for gender (male = 1), A for age, P for body mass and MAS for maximum aerobic speed (MAS) (8).

Standing height was measured at the nearest 0.1 cm, followed by body mass at the nearest 100 g, respectively, with a 206 mural stadiometer (Seca-Bodymeter, France) and an electronic scale Qe- XY-3012 (Camry, China). For each variable, three successive measures were taken and the mean value was calculated. The training load (TL) was calculated applying the formula: TL = total number of training sessions x duration of the sessions x (HRe - HRr/HRmax - HRr) (4). At the end of each training session, the players expressed their subjective perception of effort (Pse) on the Borg scale (5). The physiological strain index (PSI) was determined using the formula: PSI = 5(Trece - Trecr)/(39.5 - Trecr) + 5(HRe - HRr)/(180 - HRr), as well as the assessment scale proposed in the literature (21).

Players were subjected to three weekly outdoors training sessions of 90 minutes in the afternoons, for six weeks. The exposure temperature and relative humidity oscillated respectively between 30 and 34 °C and 58 and 62%. The usual training program and content performed during the specific preparation stage of the champion team served as reference. Both IG and CG groups followed together, a part of this usual program. Instead of the sequences reserved to the technico-tactical learning sequences proposed to the CG group in the main part of each session, the IG group performed a sequence of specific exercises in the form of a specific circuit training (SCT) according to the 15-15 (15-second of high intensity work and 15-second recovery period) modality (Figure 1).

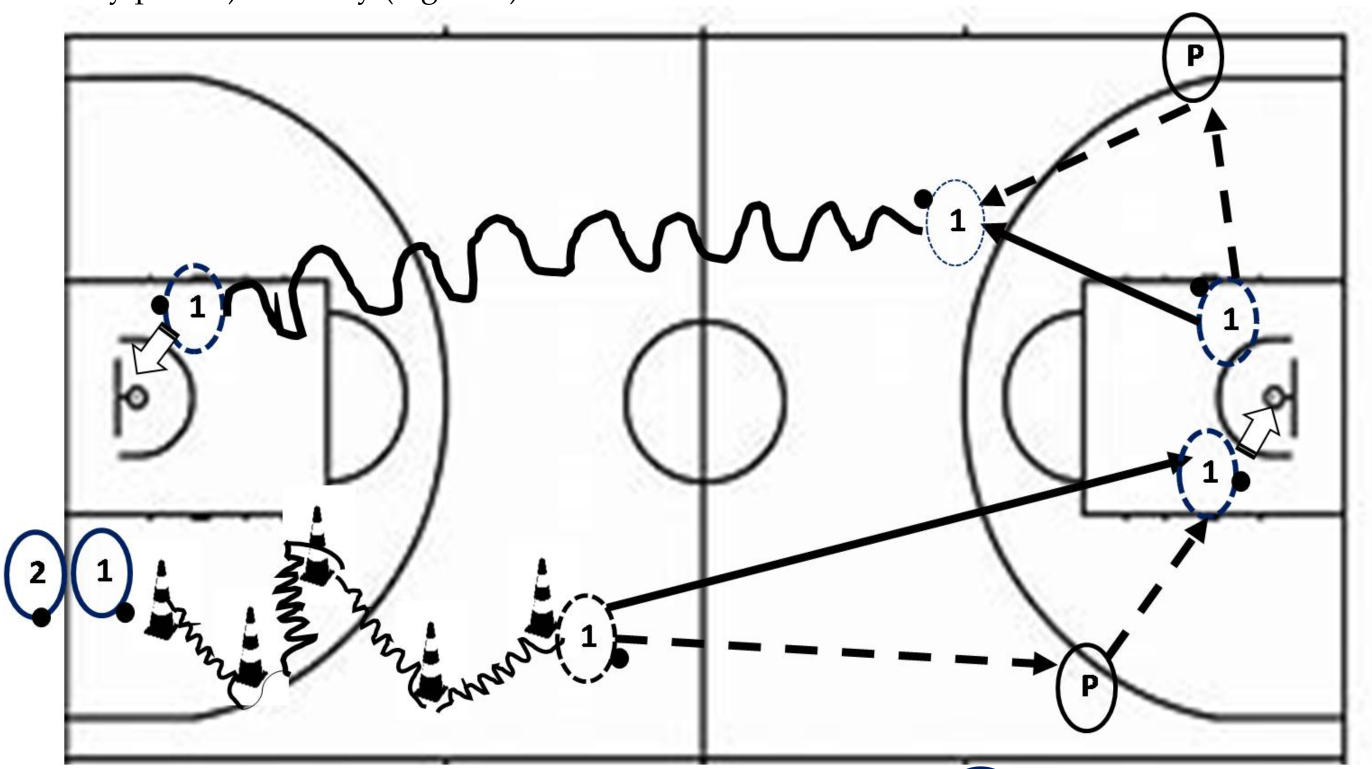

Figure 1. Schematic representation of the technical circuit. : ball player. : player number 1. : player number 2. : passing player. : ball. : cone. : dribble. : shoot. : pass. : player running.

Contents of the different programs carried out are showed in figure 2. The specific 15-15 circuit training was organized using the repetitions and series format, i.e 10 repetitions of 15-second high intensity drill and 15-second recovery period, were considered as 1 series. There were 2 min 30 s of active recovery between series. In the whole, 5 series were undertaken within the 35 min of workout. Active recovery consisted of free throw and hydration.

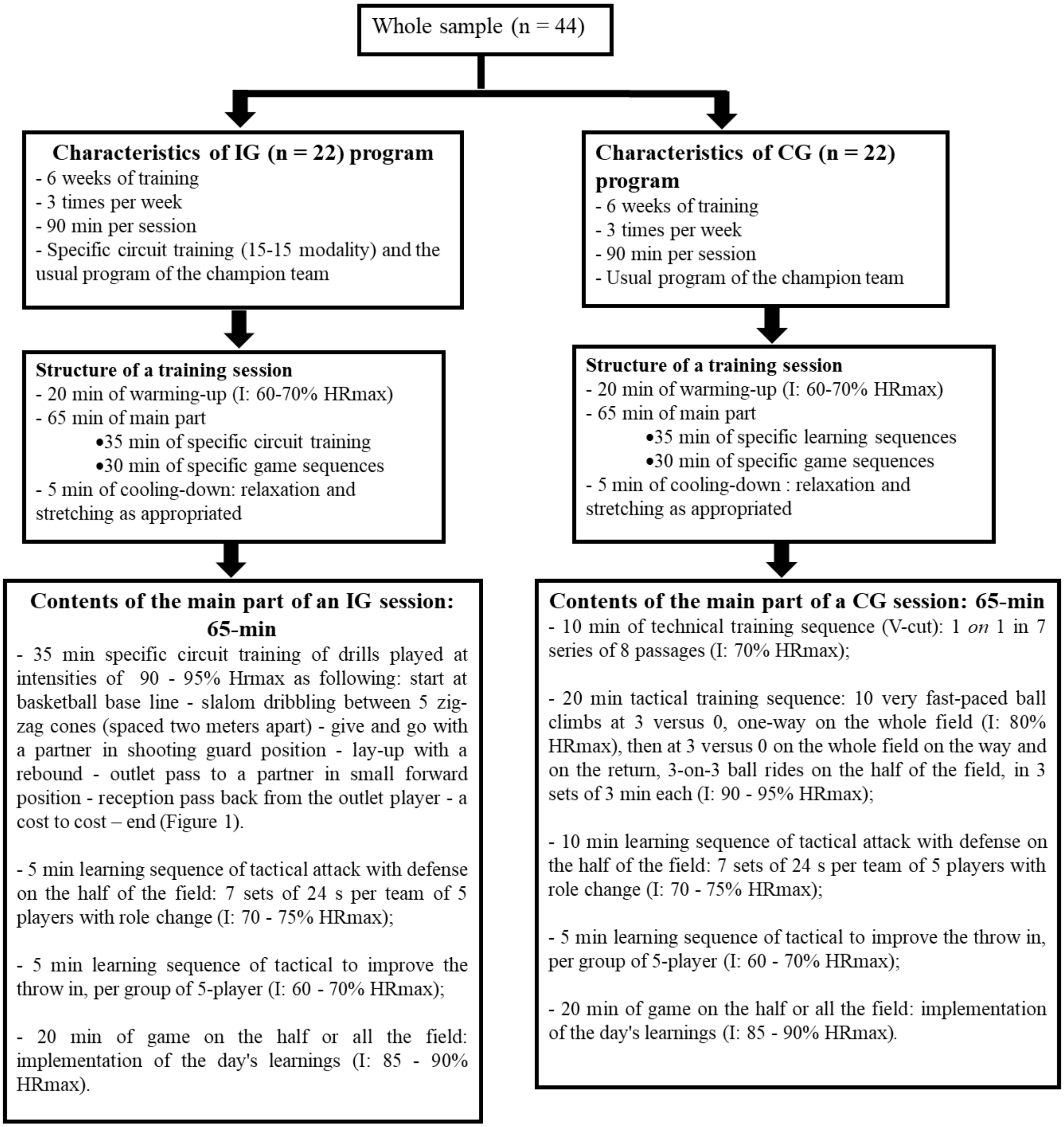

Figure 2. Intervention design. I: intensity. HRmax: maximal heart rate. IG: intervention group (n= 22). CG: control group (n = 22).

Statistical Analysis

The data were analyzed using Statistica software (Stat Soft Inc., Version 12). The normality of variables' distribution was checked using the Kolmogorov-Smirnov test. The data are presented as mean value ± standard deviations (s). Pre-training to post-training differences in groups (IG and CG) and between groups were explored as appropriate with respectively a paired and unpaired Student t-tests. For all comparisons, the level of statistical significance was set at $p < 0.05$.

RESULTS

There was no significant difference between both groups (Table 1) at pre-training for any study variable ($p > 0.05$). No player was on medication that could influence cardio-respiratory function and had no personal or family history of heart or respiratory disease or diabetes.

Table 1. Anthropometric characteristics and practice history sports of the studied basketball players (n = 44).

	Intervention group (n = 22)	Control group (n = 22)	p value	Whole sample (n = 44)
Age (years)	25.4 ± 4.6	23.6 ± 3.3	0.15	24.5 ± 4.0
Height (cm)	184.4 ± 10.2	182.9 ± 7.4	0.58	183.7 ± 8.8
Body mass (kg)	79.9 ± 10.4	75.8 ± 8.4	0.16	77.8 ± 9.6
BMI (kg/m^2)	23.4 ± 1.8	22.6 ± 2.4	0.26	23.0 ± 2.1
Seniority (years)	10.3 ± 5,0	9.6 ± 4.0	0.62	10.0 ± 4.5
THW (h)	9.3 ± 2.7	8.3 ± 2.4	0.20	8.8 ± 2.5

Values in the boxes represent mean values ± standard deviation; n: sample size; BMI: body mass index; THW: number of training hours per week; seniority; years of practice.

After the six-week training period (Table 2), $\dot{V}O_2max$ increased by 6.5% ($p < 0.001$) in IG, but its variation of 0.3% was non-significant in CG ($p = 0.50$). HRR1 decreased in IG and CG, respectively, by 14.2% ($p = 0.01$) and 14.1% ($p = 0.03$) without a significant difference between both groups. HRR2 did not significantly vary in any of the groups ($p > 0.05$). However, the difference observed between HRR1 and HRR2 in IG was significant, i.e. Δ of 13 ± 8 bpm *versus* 23 ± 8 bpm = 10 ($p = 0.001$) and greater than that recorded in CG with a Δ of 10 ± 6 bpm *versus* 14 ± 6 bpm = 4 ($p = 0.09$) at the end of the training period. In addition, the mean HRR2 was higher in IG than in CG (63 ± 8 bpm *versus* 57 ± 6 bpm, $p = 0.003$) at the end of the training period. SBP increased by 5% and 4% ($p < 0.001$) respectively in IG and CG groups with no significant difference between them ($p > 0.05$). The variation of 1.9% of DP in IG was non-significant ($p = 0.42$) while it increased by 7.2% ($p < 0.001$) in CG.

Data recorded during training sessions (Table 3), indicate that the mean values were higher in the IG than in CG for all parameters ($p < 0.05$) except for resting HR, HRmax, percentage of HRmax and Trec which did not show any significant difference between both groups ($p > 0.05$). At the end of the training period, changes in HRr were not significant in either group ($p > 0.05$).

Table 2. Comparison of cardiac and physiological parameters at different measurement times between intervention and control groups (n = 44).

	Intervention group (n = 22)		Control group (n = 22)	
	Measures 1	Measures 2	Measures 1	Measures 2
Rest heart rate (bpm)	58 ± 6	56 ± 5£	58 ± 5	59 ± 3£
Maximal heart rate (bpm)	187 ± 10	189 ± 6£	185 ± 12	184 ± 6††
HR at 1 min recovery (bpm)	140 ± 8	149 ± 12**	134 ± 10†	140 ± 10††
HR at 2 min recovery (bpm)	127 ± 10	126 ± 8£	123 ± 8	126 ± 6£
HRR1 (bpm)	46 ± 10	39 ± 8*	50 ± 11	43 ± 9*
HRR2 (bpm)	59 ± 14	63 ± 8£	61 ± 12	57 ± 6£
SBP(mmHg)	120 ± 2	126 ± 4*	124 ± 3	130 ± 3*
Double product (mmHg/min)	7023.8 ± 910.1	7159.6 ± 776.0£	7257.8 ± 634.6	7787.1 ± 458.1**††
$\dot{V}O_2max$ (mL/min/kg)	50.4 ± 3.1	53.7 ± 3.6***	50.3 ± 2.8	50.4 ± 2.9†

Values in the boxes represent mean values ± standard deviations; n: sample size; Measures 1: measurements at the start of the training period; Measures 2: measurements at the end of the training period; HR: heart rate; HRR1: heart rate recovery at 1 minute following the end of the exercise; HRR2: heart rate recovery at 2 minutes following the end of exercise; bpm: beats per minute; SBP: systolic blood pressure; $\dot{V}O_2max$: maximum oxygen consumption; *: difference between measures 1 and 2, significant at $p < 0.05$; **: difference between measures 1 and 2, significant at $p < 0.01$; ***: difference between measures 1 and 2, significant at $p < 0.001$; †: difference between intervention and control groups, significant at $p < 0.05$; £ : no statistical significant difference i. e. $p \geq 0.05$.

Table 3. Comparison of data recorded by basketball group during training sessions (n = 44).

	Intervention group (n = 22)	Control group (n = 22)	p value
Resting heart rate (bpm)	56 ± 5	59 ± 3	0.02
Maximal heart rate (bpm)	189 ± 6	184 ± 6	0.59
Exercise mean heart rate (bpm)	140 ±1	134 ± 1	< 0.001
Percentage of maximal heart rate (%)	74.3 ± 2.3	73.2 ± 2.5	0.14
Percentage of weight loss (%)	1.2 ± 1.2	-0.1 ± 1.4	0.008
Subjective perception of effort (points)	14.8 ± 0.5	13.3 ± 0.6	< 0.001
Training load (AU)	685.0 ± 36.8	654.3 ± 33.3	0.006
Resting rectal temperature (°C)	36.3 ± 0.1	36.3 ± 0.0	0.23
Post training rectal temperature (°C)	37.4 ± 0.1	37.3 ± 0.0	0.07
PSI	5.6 ± 0.3	5.1 ± 0.1	< 0.001

Numbers in the boxes represent means ± standard deviations; n: sample size; bpm: beats per minute; AU: arbitrary unit; PSI: physiological strain index (22).

DISCUSSION

The purpose of this study was to assess the effects of a training program of a technical circuit, using the 15-15 modality of interval training method on selected physiological parameters in national top-level basketball players. Interval training may induce rapid improvement in general physical abilities and optimize athlete performance (6). The 15-15 modality has been selected because medium to high intensity actions in basketball game i. e. 15 s of game action and 15 s of relative recovery are more frequent (24). The resting heart rate and blood pressure used to estimate the oxygen consumption of the myocardium through the double product were measured about 60-30 min before the players ran the 30-15 IFT. This can be considered a limitation of this study but as this parameters have been measured under the same conditions before and after the training period, the value of double product may be reflect the effect of training. While recognizing that these two parameters may have been overestimated, due to the stress linked to the upcoming physical test, one must take in mind that the study was mainly designed for assessing the effect of the training loads on the myocardium oxygen consumption. In the current study, the technical skills trained and the hydration status of the players were not assessed. It is therefore not possible to know whether the hydration status has damaging effects on the study variables or whether the program used and its content, have improved the technical skills of players, even though positive results have been reported in previous works in which this kind of skills have been studied (9, 19).

After the six-week training period, heart rate at one minute decreased in both groups. In contrast, recorded heart rate recovery at two-minute changes, has not changed but the variation observed between the recovery heart rate at one-minute and two-minute in the intervention group was greater than that of the control group. The variation in the double product recorded in the intervention group was not significant, but it increased in the control group. VO_2max increased in the intervention group, but not in the control group. These results have been obtained under moderate physiological strain index (PSI = 5) with a hard subjective perception (RPE between 13.3 and 14.8 points) of the training load as it was expressed by the players. This additional heat load due to the environment in which the players evolved and the physical requirements of the training drills were necessary to induce physiological adaptations in their bodies and mainly in their oxygen supply pathways ("Discussion", paragraph 2).

$\dot{V}O_2$max increased in the intervention group, while the variation observed in the control group was non-significant. $\dot{V}O_2$max varies with genetics, age, gender, training level and other factors (29). The players studied were male, lived in the same environment and did not differ significantly from each other at the beginning of the study with respect to age, as well as $\dot{V}O_2$max. The training followed may therefore have caused the increase in $\dot{V}O_2$max observed in the intervention group. Specific circuit training in the 15-15 modality appeared more effective for improving $\dot{V}O_2$max than the usual program alone. In fact, the higher weekly training load in the specific circuit-training group in this study may explain some of the differences recorded between both groups. Although a potential inter-individual variation of training effects, interval training has been reported to be effective for $\dot{V}O_2$max improvement and the results are all the more important as the intensity of the exercises is high (3, 6).

Cardiac recovery after exercise refers to the magnitude of the decrease in heart rate observed within the first few minutes following physical exercise (11). This drop in heart rate is often attributed to the restoration of parasympathetic/vagal tone, which increases during the first four minutes of recovery, depending on the intensity of the exercise (11, 16). Thus, at the end of an exercise, the heart rate drops rapidly within the first minute, mainly due to parasympathetic reactivation (10). The decrease in heart rate continues in the following minutes, but more slowly, due to the slower reduction in the sympathetic activity, concentration of circulating catecholamine and the greater restoration of vagal tonicity (14). The decrease in the one-minute heart rate recovery, observed at the end of the training program in both groups suggests therefore, an increase in the speed at which the heart rate drops. An increase that could be the result of the training stimuli entail, among other things, a faster reactivation of vagal tonicity at the end of the effort (14).

The increase in heart rate recovery speed after two minutes in the intervention group could be understood as a positive effect of the training program on the myocardia. However, this increase is less significant than that recorded after one minute. The lower variability in the two-minute recovery heart rate compared to the one minute's in both of the groups, confirms that the recovery speed is greater during the first minute. Results similar to those of the current study about the one-minute cardiac recovery were recorded after nine weeks of training among semi-professional basketball players (2) and cyclists (27). These results raise the question of the relevance of both indices when assessing the effects of training on the capacity of recovery of athletes' heart rate recovery capacity. The heart rate should be monitored over very short post-exercise times, i.e. between 30s and 120s, for the analysis of heart recovery in basketball players.

In turn, the double product did not change significantly in the intervention group, while it increased in the control one. The double product is considered as a relevant parameter in assessing ventricular function, as well as myocardial oxygen consumption, which reflects the cardiac hemodynamic workload (25, 26). The determinants of this parameter are heart rate, myocardia contractility and stress on the ventricular wall, factors whose values are modulated by sympathetic and parasympathetic nervous systems (13, 26). A decrease in the double product is considered as an indicator of high parasympathetic activity and lower myocardial oxygen demand (13, 18). An increase in this parameter in the control group would therefore reflect low parasympathetic activity and an increase in coronary blood flow in response to atrial stimulation (26). A decrease in the double product has been reported in less active individuals assigned to a 12-week training program, including exercise at high or moderate intensities (18). At this time, it is difficult to explain the lack of variation in the double product in the intervention group. Further studies are needed to confirm this trend. The groups worked at similar intensities, i.e. at the percentages of 74% and 73% of HRmax that can be considered relatively low. Unlike the usual program, the specific circuit training did not have an effect on the oxygen consumption of the myocardia.

This study confirmed the positive effect of interval training on $\dot{V}O_2$max. The results revealed that the specific circuit training in the form of interval training in the 15-15 modality improved the recovery rate of the heart at one and then at two minutes but had little effect on myocardial oxygen consumption. The use of the specific circuit training, thus appears to be an effective training strategy that physical trainers can now use to improve the physical and heart recovery abilities of basketball players. Further studies should be carried out with the women and with different age groups to confirm these results and extend their reach. They should also look at the effects of the technical circuit in the form of specific interval training on other physical abilities such as the repeated sprints ability and the sports skills of basketball players.

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