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Five Weeks Cross-Training Effects on the Physical Performance of Elite Football Referees in Benin

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Abstract

Introduction: Cross-training is effective in developing the physical abilities of athletes, but its short-term effects are little known among referees. The purpose of this study was to determine the effects of a five-week cross-training block on the physical performance of soccer referees. Methods: It was carried out with 18 elite referees in Benin, divided into two equal groups: one experimental group (EG) and the other control group (CG), respectively subject to cross-training and ordinary training. The tests of squat jumps, counter movement, isolated sprints over 10 m, over 40 m, Illinois agility, capacity for repeated sprints and the Yo-Yo IRT2 were carried out before (M1) and after (M2) training. The Wilcoxon and Mann Whitney U rank tests were used for comparisons between M1 and M2, then between EG and CG. Results: At the end of training, $\dot{V}O_2max$ (+2.8% versus +0.2%; $p = 0.0004$), squat jump height (+8.1% versus +0.7%; $p = 0.002$), counter movement (+6.0% vs +1.0%; $p = 0.04$), performance in isolated sprint tests over 10 m (−3.7% vs −0.0%; $p = 0.02$), 40 m (−16.4% vs −0.04%; $p = 0.0003$), Illinois Agility (−1.3% vs −0.5%; $p = 0.03$), repeated sprints (−2.1% vs −0.1%; $p = 0.001$) were more improved in GE than in GC. Conclusion: In five weeks, cross-training improved the physical abilities that determine the performance of the football referee. Its long-term effects will need to be assessed to complete these results.

Keywords

Football Referees, Cross-Training, Physical Tests, Benin Republic

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#Posthumous.

1. Introduction

The football referee is an essential actor for the progress of the matches (Fabrice et al., 2011). He is responsible for applying the rules of the game, controlling the behavior of players and ensuring their physical integrity (Reilly & Gregson, 2006). They must evaluate and judge actions, be in the right place at the right time, make split-second decisions, maintain order, limit and resolve conflicts (Fabrice et al., 2011). Compared to other actors directly involved in the game, errors by referees are the least tolerated (Castagna et al., 2007). To support referee performance, FIFA has developed initiatives in recent years, the most recent of which are goal-line technology and video assistant refereeing (VAR).

The performance of football referees results from the interaction of psychological, cognitive, technical, physical and physiological factors (Fabrice et al., 2011). Physical and physiological factors are the most determining factors in modern football in that they represent a requirement for success in high-level refereeing (Weston et al., 2012). Good physical and physiological abilities allow referees to follow the imposed pace of play, to be in the right place at the right time, in order to make appropriate decisions (Oliveira et al., 2011) and delay the onset of fatigue. They also prevent the risk of injuries caused by the physical loads imposed on the muscular and cardio-respiratory systems during matches (Gabrilo et al., 2013).

A high-level central referee covers an average of nine to 13 km per official match, of which four to 18.4% are high-intensity runs (Weston et al., 2012). On average, he performs 161 sprints at an average time interval of 30 seconds and 800 to 1000 changes of direction (Krustrup & Bangsbo, 2001). The average heart rate, oxygen consumption and blood lactate concentration of the latter reach 85% to 90% of the maximum heart rate, 70% to 80% of the $\dot{V}O_2max$ and four to five mmol/L respectively (Castagna et al., 2007). A water loss of 1.60 ± 0.13 L and a significant decrease in plasma volume of 4.99% ± 1.33% are observed in the referee (Da Silva & Fernandez, 2003).

An elite assistant referee covers between six and eight kilometers per match, of which 10% to 30% is done in sideways shuffling (Krustrup et al., 2009). He performs 1050 to 1150 different activities changing every 4 to 5 seconds and performs an average of 110 high-intensity activities over an average duration of 2 seconds (Krustrup et al., 2002). The average heart rate and oxygen consumption of the assistant referee reach 76% of the maximum heart rate and 65% of the $\dot{V}O_2max$ respectively (Reilly & Gregson, 2006). A loss of water of 0.79 ± 0.19 L, equivalent to a decrease of 1.05% ± 0.25% in body mass and a non-significant decrease in plasma volume are reported in the latter (Da Silva & Fernandez, 2003).

These requirements imply that referees must undergo appropriate physical training to develop their physiological and physical capacities in order to perform well (Weston et al., 2012). Physical training in interval training, carried out at a frequency of three to four sessions per week, was recommended to referees

(Castagna et al., 2007; Weston et al., 2012). Currently, different physical training methods such as cross-training, concurrent training and complex training are used in team sports. Cross-training is the one that has shown its effectiveness in developing the athlete's general physical abilities (Paquette et al., 2018). On the other hand, it does not seem to be as effective when it comes to developing the specific technical abilities of players in a given sport (Paquette et al., 2018).

Currently, there is almost no work on the effects of cross-training on the physical performance of football referees in general and those in West Africa in particular. This is why it seemed necessary to us to implement the present study. Thus, the objective of the study was to evaluate the short-term effects of cross-training on the physical abilities of football referees in southern Benin. In particular, it was to measure the changes induced by a five-week cross-training block on $\dot{V}O_2max$ and on performance in jumping, sprinting and agility tests.

2. Materials and Methods

2.1. Protocol

This was an intervention study (Figure 1), carried out with elite football referees, i.e. FIFA and federal grade referees registered on the official list of the Beninese Football Federation. The selected referees were subjected either to a cross-training training block (Experimental group: EG), or to their ordinary training protocol (Control group: CG). $\dot{V}O_2max$, anthropometric measurements, urinary specific gravity, squat jumping, countermovement jumping, 10 m and 40 m isolated sprints, Illinois agility, repeated sprinting ability were performed before the start and after the last training session. Before carrying out the study, the referees were interviewed on the objective, the procedure, the advantages and the risks associated with the study, then each gave their free, informed written consent.

2.2. Participants

Male referees of FIFA or federal grade under the Regional Commission of Referees of Ouémé-Plateau in southern Benin constituted our study population. A total of 18 referees, including eight FIFA grade and 10 federal grade referees

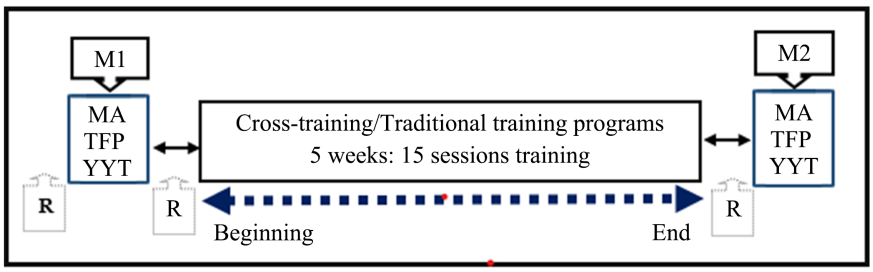

Figure 1. Study implementation plan. M1: measurements taken before the start of the training period; M2: measurements taken at the end of five weeks of training; AM: anthropometric measurements; PFT: physical field tests; YYT: Yo-Yo IRT2 for indirect estimation of maximum oxygen consumption (Bangsbo et al., 2008); R: 72-hours rest.

participated in the study. These referees were divided by random assignment into two equal groups, one control group (CG: n = 9) and the other experimental group (EG: n = 9) each comprising four FIFA referees and five federal. EG was put through a cross training block and CG went through the usual training protocol.

2.3. Measurements

Height was measured with a body meter wall height chart (Seca 206, France). A multifunction electronic bio-impedance meter (Terraillon, China) was used to measure mass and percentage of body fat. Abdominal circumference was measured with a tape measure. An Optech K 71903 clinical refractometer (Exacta, Germany) was used to measure urine specific gravity. The Optojump Next system (Microgate, Italy) made it possible to measure the height in centimeters of squat and counter-movement jumps. Photoelectric cells (Brower Timing system, USA) placed at the start and at the finish were used to measure running times in seconds for the tests of isolated sprints over 10 m, over 40 m, repeated sprint capacity and agility. A CD player and an amplifier were used to broadcast the Yo-Yo IRT2 beeps (Bangsbo et al., 2008). The order of performance of the various field tests was as follows: squat jump, counter-movement jump, isolated sprint over 10 m and 40 m, test of agility and repeated sprint capacity. Between two tests, 6 min to 8 min of rest were granted to the referees. The 10 m, 40 m and agility sprint tests were carried out in three trials, the best result was retained as performance.

A 105 MT 401R automatic thermometer (Cooper, France) was used to measure the rectal temperature immediately after the end of the last sequence of sessions. Each referee had an automatic thermometer on which his name was written, as well as cotton and alcohol to clean the thermometer after each use. The resting and maximum heart rates at which the sessions took place were measured by an RS 400 heart rate monitor (Polar, Finland). At the end of each training session, the referees expressed individually on the Borg scale (Borg, 1970), the perception they had of the effort provided. Ambient temperature and relative humidity were recorded during each session using a Météo Star multifunction device.

2.4. Training

Training took place during competition. It lasted five weeks, with three weekly sessions of one hour and twenty minutes to one hour and thirty minutes each, simultaneously for the two groups and in the morning. During the first three weeks, the referees of the experimental group followed the mini block 1 in cross-training and those of the control group the microcycle 1 of the traditional training. The last two weeks were devoted to mini block 2 and microcycle 2, respectively for EG and CG. During the sessions, a 5 min break was observed between the sequences. Ambient temperature and relative humidity varied from 22˚C to 24˚C and from 85% to 90% respectively.

2.4.1. Block of Cross-Training

It consisted of two mini blocks. Mini block 1 consisted of the common sequence with the control group and two specific sequences, namely muscle strengthening and fartleck. During this mini block 1, the sessions began with a 15 min warm-up, followed by muscle strengthening sequences (using body weight) of 15 min, a 75 m sprint of 25 min and a fartleck of 25 min (Table 1). Mini block 2 included three specific exercises which are muscle strengthening, fartleck and

Table 1. Content of the training block in cross-training for five weeks (15 sessions).

Blocks	Sequences	Duration	Tasks and instructions
1 et 2	Warm up	15 min	- Slow run around the athletics track: 5 min. - Educational running (heels to buttocks, knees to chest, alternate leg swings) and dynamic stretching: 5 min
1 et 2	Muscle building: specific exercise 1	15 min	- Flexions-extensions; jump rope; multidirectional hops; skipped lunges; strengthening of the muscles of the abdominal wall: right flexion-extension, flexion-extension with twist to the right and left; cladding (planes: anterior, posterior and lateral) push-ups. 2 sets, 30 s of effort per exercise, 30 s of recovery between exercises and 2 min of rest between sets; execution at maximum speed.
1	75 m sprints: joint exercise	20 min	- Alternate 75 m sprint with active recovery walking for 25 m around the athletics track: number of sprints = 18 to 24, sprint duration = 15 to 20 s, recovery duration = 20 to 30 s
1 et 2	Fartleck: specific exercise 2	25 min	Perform alternatively: - 60 m sprint, followed by 40 m active recovery around the athletics track: 12 reps, sprint time = 10 s, recovery time = 30 s; - Ascent at maximum speed of 60 bleacher steps in a sprint, followed by a slow descent: 3 chained repetitions. - Walking the width of the football field, fast running in 25 s on the diagonal, running backwards on the opposite width, fast running in 25 s on the opposite diagonal: 3 repetitions. - Ascents at maximum speed of 30 bleacher steps in jump with feet together and slow descent: 3 repetitions, followed by 3 laps of the athletics track by performing each of the following exercises alternately over 40 m; sprint, slow run, sideways jog left side at maximum speed, run backwards at maximum speed, sideways jog right side at maximum speed and walk; - Ascent of 20 steps on one step alternately with the right leg and the left leg, followed by a slow descent: 2 repetitions. - Passer-receiver relationship and shots; Ascent of the ball in pairs at maximum speed over 30 m followed by suspension shooting: 2 series of 5 repetitions, 30 s of passive recovery between the repetitions and 3 min of rest between the series.
2	Handball: Specific exercise 3	30 min.	- Game with reduced numbers: 4 against 4 on the whole field with change of goalkeeper every 2 min: 2 sequences of 6 min, 3 min of active rest between the sequences.

The sequences are presented according to the chronological order of their execution; muscle strengthening exercises were performed using body weight; abdominals: exercises intended to strengthen the abdominal wall muscles; push-ups: flexion-extensions of the thoracic limbs; the rise exercises were carried out on the bleachers of the spectator stand inside the stadium.

handball. During this mini block, the sequences followed one another in the following order: 15 min warm-up, 15 min muscle strengthening, 25 min fartleck and 30 min handball.

2.4.2. Traditional Training

It consisted of two micro cycles. Micro cycle 1 included sequences: sprints, joint, muscle strengthening of the pelvic limbs, abdominals and cladding (using body weight). Micro cycle 2 also consisted of the same types of sequences apart from the common sequence. During micro cycle 1, the training started with a 15 min warm-up, followed successively by: specific sequence of running at maximum speed over 40 m of 15 min, common sequence of 25 min, specific sequence of strengthening of the pelvic limbs of 15 min and specific sequence of abdominals then cladding of 10 min (Table 2). During micro cycle 2, the order of execution of the sequences was as follows: warm-up of 15 min, rapid runs over 100 m or respectively over 100 m, 90 m, 80 m, 70 m, 60 m and 40 m of 30 min; strengthening of the pelvic limbs for 15 min and of the abdominals then sheathing for 10 min (Table 2).

Table 2. Content of the traditional training program for five weeks (15 sessions).

Microcycle	Sequences	Duration	Tasks and instructions
1 et 2	Warm up	15 min	- Slow run around the athletics track: 5 min - Educational running (heels to buttocks, knees to chest, alternate leg swings) and dynamic stretching: 5 min.
1	40 m sprints specific exercise 1	15 min	- Sprint over 40 m alternated with passive recovery: number of sprints = 10, sprint duration = 6 s, recovery duration = 1 min.
1	40 m sprints specific exercise 1	15 min	- Sprint over 40 m alternated with passive recovery: number of sprints = 10, sprint duration = 6 s, recovery duration = 1 min.
2	Sprints: specific exercise1	30 min	- 100 m sprint, active recovery between 100 m sprints around the athletics track: running time 20 s, recovery time 30 s. Or - Sprints on respectively: 100 m, 90 m, 80 m, 70 m, 60 m, 50 m and 40 m on a length of the athletics track with active recovery between sprints: duration of races 20 s, 18 s, 16 s, 14 s, 12 s, 10 s and 6 s respectively, recovery time 30 s.
1 et 2	Muscle strengthening of pelvic limbs specific exercise 2	25 min	- Climbing 50 bleacher steps in a slow run and slow descent: 2 repetitions of 10 min, 5 min of passive recovery between repetitions.
1 et 2	Abdominal and sheathing exercises specific exercise 1	10 min	- Strengthening of the muscles of the abdominal wall: right flexion-extension, flexion-extension with torsion to the right and to the left; pumps; backings; sheathing (planes: posterior, anterior and lateral). 30 repetitions per exercise and 30 s recovery between exercises.

The exercises are presented according to the chronological order of their execution; abdominal and sheathing exercises are performed using body weight; abdominals: exercises intended to strengthen the muscles of the abdominal wall; push-ups: flexion-extensions of the thoracic limbs: muscle strengthening exercises for the pelvic limbs are performed on the stands of the spectators' stand inside the stadium.

2.5. Variables

The independent variable: these are measurement times operationalized in two ways: measurement before the start of the training period (M1) and measurement at the end of said period.

The dependent variables retained were the following: the height of the jumps in squat (H_{JS}) then in counter movement (H_{JCM}), running time in the isolated sprint test over 10 m ($RT_{10\,m}$), running time in the isolated sprint test over 40 m ($RT_{40\,m}$), running time in the Illinois Agility Test (RT_{IAT}), performance in the repeated sprint ability test, assessed on the basis of the average running time (RSA_{mean}) at the six passages of repeated sprints and the $\dot{V}O_2max$, estimated from the result of the Yo-Yo IRT2 test (Bangsbo et al., 2008).

The confounding variables were represented by: ambient temperature (AT), relative humidity, water drunk, exercise maximal heart rate, rectal temperature, perception of the effort provided during the training sessions, according to the Borg scale, the percentage of weight loss, the water status determined from the urinary specific gravity and anthropometric measurements. Three methods have been defined to assess water status, namely: hyperhydrated with a urinary specific gravity less than 1.010, normohydrated with a urinary specific gravity between 1.010 and 1.020 and hypohydrated with a urinary specific gravity greater than 1.020 (Casa et al., 2000). Anthropometric measurements included height, body mass, body mass index, abdominal circumference and body fat percentage.

2.6. Statistical Analysis

The recorded data was processed with Statistica software from Stat Soft Inc. (Version 12). The normality of the distribution of variables was checked using the Kolmogorov-Smirnov test and descriptive statistics in the form of means (m) ± standard error of the mean (SEM) was calculated. Wilcoxon's non-parametric rank tests were used to compare the means between the two measurements in each group, then Mann Whitney's U for comparisons between the control and experimental groups. The significance level of the statistical tests was set at $p < 0.05$.

3. Results

3.1. Anthropometric Characteristics

Whatever the characteristic considered (**Table 3**), the differences observed between the groups of referees studied were all non-significant ($p > 0.05$).

3.2. Physical and Physiological Performances

At the end of the training period (**Table 4**), performance improvements were greater in EG than in CG ($p < 0.05$) regardless of physiological or physical capacity considered except for urinary specific gravity ($p = 0.72$). These are: $\dot{V}O_2max$ (+2.8% versus +0.2%; $p = 0.0004$), $RT_{10\,m}$ (−3.7% versus −0.01%; $p = 0.02$), $RT_{40\,m}$ (−16.4% versus −0.04%; $p = 0.0003$), RT_{IAT} (−1.3% versus −0.5%;

Table 3. Anthropometric characteristics of participants (n = 18).

	Experimental group (n = 9)	Control group (n = 9)	*p*
Age (years)	29.8 ± 4.8	31.0 ± 6.3	0.79
Height (cm)	175.7 ± 0.0	173.2 ± 0.0	0.56
body mass (kg)	67.8 ± 7.3	69.4 ± 10.8	0.62
body mass index (kg/sq·m)	22.5 ± 2.0	22.3 ± 2.1	0.82
abdominal circumference	76.2 ± 4.8	79.4 ± 6.6	0.33
Percentage of body fat %	16.6 ± 2.9	17.3 ± 3.5	0.72
resting heart rate	58 ± 4	59 ± 2	0.50
NAAF (years)	10.3 ± 4.5	11.1 ± 4.8	0.56

Numbers in boxes represent means (m) ± standard deviations (s); n: count; NYFR: Number of years spent in football refereeing.

Table 4. Changes in physical and physiological parameters recorded after the training period.

	Experimental Group (n = 9)		Control Group (n = 9)	
	M1	M2	M1	M2
$\dot{V}O_2$max (mL/min/kg)	55.81 ± 0.41	57.38 ± 0.33**	55.51 ± 0.49	55.63 ± 0.44†††
$RT_{10\,m}$ (s)	2.16 ± 0.08	2.08 ± 0.08**	2.15 ± 0.07	2.15 ± 0.07†
$RT_{40\,m}$ (s)	5.50 ± 0.09	5.41 ± 0.09**	5.49 ± 0.06	5.49 ± 0.07†††
RT_{IAT} (s)	16.18 ± 0.22	15.96 ± 0.23**	16.27 ± 0.30	16.17 ± 0.23†
RSA_{mean} (s)	5.48 ± 0.06	5.36 ± 0.06**	5.48 ± 0.08	5.49 ± 0.06††
H_{SJ} (cm)	34.24 ± 1.31	36.85 ± 1.26**	34.51 ± 0.86	34.77 ± 1.11††
H_{JCM} (cm)	37.43 ± 1.25	39.68 ± 1.32**	37.57 ± 1.34	37.96 ± 1.67†
USG	1.016 ± 0.00	1.004 ± 0.01**	1.018 ± 0.00	1.007 ± 0.03**

Numbers in boxes represent means (m) ± standard errors of the mean (sem); n: count; M1: measurement recorded before the start of the training period; M2: measurement recorded at the end of the training period; $\dot{V}O_2$max : maximal oxygen consumption estimated from Yo-Yo IRT2 results (Bangsbo et al., 2008): $RT_{10\,m}$: 10 m sprint running time; $RT_{40\,m}$: 40 m sprint race time; RT_{IAT}: Illinois Agility Test race time; RSA_{mean}: mean time of six sprints in the repeated sprint ability test; H_{SJ}: the height of the squat jump; H_{JCM}; the height of the jump in counter movement; USG: Urinary specific gravity; **; difference between measurements taken before and at the end of the training period significant at $p < 0.01$ in the same group; †: significant difference at $p < 0.05$ between the mean differences of the experimental group and the control group; ††: significant difference at $p < 0.01$ between the mean differences of the experimental group and the control group; †††: significant difference at $p < 0.001$ between the mean differences of the experimental group and the control group.

$p = 0.03$), RSA_{mean} (−2.1% versus −0.1%; $p = 0.001$), H_{JS} (+8.1% versus +0.7%; $p = 0.002$), H_{JCM} (+6.0% versus +1.0%; $p = 0.04$).

3.3. Data Recorded during Training Sessions

The perception of the effort provided during the training sessions according to the Borg scale ($p = 0.003$), the maximum heart rate at which the sessions took place ($p = 0.03$), the percentage loss of weight ($p = 0.02$) and rectal temperature ($p = 0.04$) were greater in EG than in CG (Table 5). The difference observed between the two groups in terms of the amount of water drunk and the number of games coached during the training period was all non-significant ($p > 0.05$).

4. Discussion

The aim of the study was to determine the changes in physical performance induced by five weeks of cross-training training in football referees in southern Benin. The limit of this study is the number limited of participants, which does not allow the generalization of the results and the failure to take into account dietary and nutritional factors. The comparison of the results with those of the players is another limitation. This is due to the fact that we could not find any studies relating to the effects of specific training programs on the physical abilities of football referees. However, apart from the technical-tactical aspects integrated into the training of players, the latter prepare themselves physically like referees with similar metabolic and physiological requirements (Castagna et al., 2007).

Table 5. Data recorded in each group during training sessions.

	Experimental Group (n = 9)	Control Group (n = 9)	*p*
HRr (bpm)	61 ± 2	60 ± 8	0.77
HRmax (bpm)	185 ± 5	177 ± 8	0.03
Trec (˚C)	38.8 ± 0.08	37.9 ± 0.15	0.04
% WL (%)	1.07 ± 0.10	0.85 ± 0.04	0.02
PEF_{BORG}	15.2 ± 0.05	13.8 ± 0.11**	0.0003
Drinking water (L)	1.25 ± 0.13	0.97 ± 0.11	0.18
NGC	6 ± 4	6 ± 5	0.85

Numbers in boxes represent means (m) ± standard errors of the mean (sem); HRr:; HRmax: maximum heart rate at which the sessions took place; %WL: percentage of weight loss recorded at the end of the training sessions; Trec: rectal temperature recorded at the end of training sessions; PEF_{BORG}: perception of the effort provided during training sessions, according to the Borg scale (Borg, 1970); NGC: Number of games coached during the training period; **: significant difference at $p < 0.001$ between the referees of the Experimental Group and those of the Control Group.

At the end of the training period, the improvement in $\dot{V}O_2max$, performance in the 10 m and 40 m sprint tests, repetitive sprint capacity and agility, jump height in squats and counter movement was more important in the group of referees subjected to the cross-training than in that which followed the ordinary program.

Before training, there were no differences between the two groups with regard to anthropometric characteristics, the number of years spent in refereeing and water status. At the end, the two groups of referees had all changed their water status, passing from the state of normohydrates to that of hyperhydrates (Casa et al., 2000). Consequently, the results were not influenced by a state of dehydration. The same is true for the number of games officiated during the training period, since regardless of the group, the referees officiated an average of six games. The maximum heart rate at which the sessions took place, the percentage of weight loss and the rectal temperature recorded at the end of the training sessions were higher in the cross-training group. These markers of the body's adaptation to exercise in a hot and humid environment reflect a higher workload in this group. The subjective perception of the effort went in the same direction, since the highest appreciation came from the group which followed the training block in cross-training.

Performance of $\dot{V}O_2max$ test: The greater increase in $\dot{V}O_2max$ in the cross-training group may be associated with the effects of fartleck sequences (Eleckuvan, 2014) and small-sided handball play (Chittibabu & Akilan, 2013). These exercises undoubtedly caused an increase in maximal cardiac output, the main determinant of $\dot{V}O_2max$ (Ozo & Sharma, 2020). The results for $\dot{V}O_2max$ are higher than those recorded for an English referee in a case study (Weston et al., 2011). The difference could result from the laboratory technique used in the latter, which the advantage of being more precise has compared to the indirect estimate by physical field tests. The improvement in $\dot{V}O_2max$ is a definite advantage. A high $\dot{V}O_2max$ allows the referee to cover more distance and repeat more sprints, which allows him to better follow the rhythm of the game (Castillo et al., 2016).

Performance of the sprints and repeated sprint capacity tests: Improvements in 10 m and 40 m isolated sprint performance in umpires subjected to cross-training bouldering may be explained by sequences of sprints and lower extremity explosive strength development that improve the excitation-contraction couple inducing faster contractions (Markovic, 2007). The reduction in sprint time over 10 m is greater than that observed in junior footballers after six weeks of training (Ingebrigtsen et al., 2013). The improvement in performance in the 40 m isolated sprint test is greater than that observed in young Norwegian footballers (Shalfawi et al., 2012). The absence of muscle strengthening of the pelvic limbs aimed at improving neuromuscular capacities and the contractile properties of the muscles (Tanaka & Swensen, 1998) in the Norwegian players' program could explain the observed difference.

Performance of the repeated sprint capacity test: The reduction in the average running time in the RSA test in referees subjected to cross-training results from neuromuscular and energy factors. Neuromuscular factors are related to improved performance at an isolated sprint (Keir et al., 2013). The energy factor is related to the increased restoration of creatine phosphate stores, which takes place during short periods of rest, thanks to a large supply of oxygen (Bishop, 2012). Indeed, a high level of $\dot{V}O_2max$ would be favorable to rapid recovery between high-intensity efforts (Dardouri et al., 2014).

The reduction in average running time in the RSA test is greater than that recorded among Croatian players (Shalfawi et al., 2012). The difference could be explained by the more demanding protocol of the players. The latter repeated 10 sprints over 40 m, recovering 60 s between sprints while the referees performed six sprints over 40 m, with 90 s recovery between sprints. The large number of sprints performed and the reduced recovery time undoubtedly constitute a high level of requirement for the protocol used in these players. Improved performance on the RSA test is an advantage since it is considered the determining factor in their physical performance as a referee (Barberó-Álvarez et al., 2014).

Performance of squat and counter-movement jump tests: The improvement in the height of squat and countermovement jumps in referees subject to cross-training would result from plyometric-type exercises for the pelvic limbs. These exercises call upon eccentric-type contractions which significantly solicit the elastic elements of the muscles involved in performing these jumps (Tanaka & Swensen, 1998). The improvement in squat jump height recorded corroborates that observed in Tunisian footballers (Chelly et al., 2010). The increase in countermovement jump height observed in this study is greater than that recorded in Croatian footballers (Jovanovic et al., 2011). The absence of work sequences of development of plyometric strength of the pelvic limbs in the training of Croatian players could justify this difference.

Performance of agility test: The reduction in Illinois Agility Test course time for referees in the cross-training group could be explained by the sequences of small-sided handball play (Iacono et al., 2015). These exercises characterized by accelerations, decelerations and various changes of direction could have favored this reduction (Horička et al., 2014). The improvement in performance in the Illinois agility test is less significant than that recorded in Hungarian footballers (Váczi et al., 2013). The length of the training period could explain this difference.

5. Conclusion

The results showed that within five weeks, cross-training training can improve the performance-determining physical and physiological abilities of football referees. Thus, referees can appropriate and now use cross-training as a method of physical training, according to a frequency of three weekly sessions. However, the long-term effects of cross-training on physical abilities are the main perspective suggested by the results of this study.

Conflicts of Interest

The authors declare no conflicts of interest according the publication of this paper.

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