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Alterations of Cardiorespiratory and Motor Profile of Paralympic 5-a-side Football Athletes during 14-Week In-Season Training

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Abstract The aim of this study was to characterize the cardiorespiratory and motor performance characteristics of blind 5-a-side footballers from the Brazilian Paralympic Team. Seven male athletes were evaluated at before and after 14-week in-season training (weekly volume between 6.5 hours to 10.8 hours), through cardiorespiratory fitness test, Agility test (5x10), Running-based Anaerobic Sprint Test (RAST) and Standing Long Jump Test (SLJT). The VO_{2max} ranged from 51.9 (±3.8) to 54.3 (±5.0) $mL.kg^{-1}.min^{-1}$.VO_2 at ventilatory threshold ranged from 48.4 (±4.4) to 41.1 (±6.8) $mL.kg^{-1}.min^{-1}$. Heart rate at ventilatory threshold ranged from 94.7 (±2.3) to 89.9 (±3.7) bpm. Regarding motor performance the values of medium Power Output ranged from 442 (± 63) to 421.9 (±66) Watts and Fatigue Index ranged from 63.1 (±9.4) to 53.9 (±14.8) W/s. Overall, our results show that while the performance of these athletes is inferior to that of professional players, their cardiorespiratory and motor performance is superior to that typical of semi-professional futsal athletes and, this study which can potentially suggest and contribute to the prescription of future training programs.

Keywords Paralympic sports, Periodization, Visual impairment, Training, Maximum oxygen uptake

1. Introduction

Paralympic 5-a-side football poses attractive possibilities as a sports practice for people with visual impairments. This has been among the Paralympic team sports for this population since Athens/Greece 2004. It has rules based on the official rules of indoor soccer FIFA with some adaptations to ensure dynamism for this modality, such as lateral barriers, non-visually impaired goalkeepers, and a bell ball.

Blind individuals tend to have limitations in spatiotemporal relations [1, 2], impaired balance adjustment, reduced ability to combine movements due to visual impairment [3] and present a deficit of coordination, factors that are associated with low neurological development of vestibular and proprioceptive [4]. Along with motor performance impairments that directly interfere in exercise prescription and planning sports training, these athletes also have a high incidence of sport injuries, of which 20% are overuse injuries in Paralympic 5-a-side football athletes [5-7].

To minimize these risks, it is essential the organization, planning and control training [7] taking into consideration the biological individuality of athletes without regard to manifestation of strength, speed and endurance, as well as, the demands of effort required by the sport. The main indicators of sports performance both in individual sports, such as collective. Are associated with the performance of the ventilation parameters and motor performance (strength and speed). The characterization of these parameters is often found in the study of non-disabled) footballers, which is similar to Paralympic 5-a-side football. For example, [8] outlined the physical and physiological profile of soccer and indoor soccer athletes. Similarly, [9] evaluated physiological responses in laboratory and field tests in indoor soccer athletes, and [10] established the physiological profile difference between professional and semi-professional indoor soccer athletes, mainly on indicators of ventilatory parameters. Regarding Paralympic sports, some authors have identified the physiological profile of wheelchair rugby [11, 12] and wheelchair basketball athletes [13]. [14] performed field assessments on physiological parameters and motor performance in disabled athletes of Paralympic modalities. Few studies have characterized cardiorespiratory profile and motor performance athletes in football 5-a-side. [15] identified significant changes in levels of VO_{2max} and

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anaerobic parameters of maximum power and fatigue index of the athletes in the work of the 16-week pre-season in six athletes with four visually impaired and two able-bodied goalkeepers. The study methodology was developed through indirect measurements in field tests and, moreover, was not recorded training content used during the analysis period. The current lack of evidence on the athletic profile and metabolic expenditure of these athletes in this sense precludes the organization of individualized training and load control adequate for the volume and intensity components [16, 17]. The aim of this study was to observe the changes in cardiorespiratory and motor profile of the Brazilian Paralympic Team athletes at the before and after 14-week in-season training. Through the results obtained, the content of training will be described for the understanding of the changes observed during the 14-week and as a suggestion for the prescription and organization of future training programs. In addition, the group will be compared with studies of futsal athletes at different levels to assess the difference between the profiles in similar modalities.

2. Purpose of the Study

The aim of this study was to observe the alterations in cardiorespiratory and motor profile of the Brazilian Paralympic Team athletes at the before and after 14-week in-season training as well compared this group with studies of futsal athletes at different levels to assess the difference between the cardiorespiratory and motor profiles in similar modalities.

3. Methods

3.1. Participants

Table 1. Sample characterization (mean±standard deviation) pre and post 14-week in-season training

Variables	Pre	Post
Age (years)	24.7±5.9	-
Height (m)	1.70±0.08	-
BM (kg)	69.3±5.3	69.0±5.7
BMI (kg/m^2)	24±1.9	23.9±2.0
BF%	11.3±2.4	10.7±1.9
BFM (kg)	7.9±1.8	7.4±1.5
FFBM (kg)	61.4±4.9	61.5±5.2

BM – Body Mass; BMI – Body Mass Index; BF% – Body Fat Percentage; BFM – Body Fat Mass; FFBM – Fat-Free Body Mass.
* denotes significant differences at $p \leq 0.05$

7 male athletes were selected from the Brazilian Paralympic 5-a-side football team. All of these athletes were functionally classified at level B1 (with residual vision up to 5% in the best eye) according to the ophthalmic classification of the International Blind Sports Association (IBSA), which governs the participation of athletes with visual impairments in all national and international competitions. Table 1 characterizes the participants, presenting anthropometric and body composition characteristics of the subjects, as well as the fluctuations of these variables throughout the 14-week in-season training. All participants provided written informed consent, as approved by the Ethics and Research Committee.

3.2. Procedures

Body Composition

Weight and height were measured according to procedures described by [2]. Body composition indicators were determined through the anthropometric method described by [2], using the Harpenden® skinfold caliper. The [18] protocol (7 skinfolds) was used to calculate body density, and body fat percentage (BF%) was determined for Siri's equation [19]. Each measurement was conducted by the same experienced experimentor.

ErgospirometricTest

The Ergospirometric evaluation was performed to obtain the athletes' maximum oxygen uptake (VO_{2max}) and maximum heart rate (HR_{max}), through an incremental ramped exercise protocol [20]. This was conducted on a treadmill (Inbramed super ATL32®) with an NGC Ultima Cardio2® ergospirometer linked to it, and a Polar heart rate monitor. The report generated from variables were developed a breath-by-breath. The test was completed and the maximum aerobic capacity was considered, when the athlete presented voluntary exhaustion, after observing an oxygen uptake plateau or peak in the last minute, RER value greater than 1.15 and/or HR_{max} higher than 90% age-predicted, criteria suggested for a test to be maximal [21].

Agility 5x10

Agility is a neuromuscular component characterized by quick change of direction and influenced by the levels of strength, speed and coordination. The agility test aimed to quantify the time spent by the athlete, to realize the distance of 5 meters with constant change of direction starting from a static position [22]. The initial position of the test adopted by the athlete was characterized by antero-posterior displacement of the legs, with the anterior foot as close as possible to the starting/finish line. To guide the evaluated athlete during direction change in this test, two examiners 'guides' were recruited to test development, and that each, was placed on each line, who shouted at different moments. When the test started, guider 1 shouted repeatedly "I" (alerting sound) alternating with a handclap. The athlete ran as fast as possible towards guider 1; when he surpassed the finish line, guider 2 on the opposite side performed the same procedure, so the athlete returned to the starting line thus completing one cycle. This move was repeated four more times, completing five cycles.

Rast Test

To evaluate anaerobic power, the running-based anaerobic sprint test (RAST) was administered according to the protocol proposed by [23]. To measure the time spent in seconds for this test, we used a photocell (Cefise/Brazil, Speed Test 6.0Std) placed on the initial and final marks the distance of 35 m. First, the individuals were weighted using a scale with precision in 0.1Kg of Plena Acqua® model, as determined in the protocol. Next, all individuals performed a 10-minute warm-up, followed by a 5-minute cool-down before initiating the test. The RAST test includes six sprints of 35 meters at maximum speed, with a 10-second of resting interval between each sprint. To guide the athlete during the test performance and in the running direction change, guiders were placed on the starting and finish lines, acting alternately. After all individuals completed the test, the following variables were calculated: maximum (PO_{peak}), medium (PO_{medium}), and minimum (PO_{min}) powers and fatigue index (FI).

Standing Long Jump Test (SLJT)

To evaluate explosive strength in the lower limbs, the athlete was placed behind the starting line with the assistance of the evaluator, with feet parallel and positioned exactly projecting the hips distance, with the tip of the toe coinciding with the starting line. The athlete jumped forward, with both legs, trying to reach as far as possible, preferably with feet parallel. Arm and trunk movement was permitted to support in jump depending on the participants preference, however, were instructed to perform the post moment similarly. After the jump, the distance between the starting line and the athlete's toe-tip final position was measured in centimeters. Each athlete had three attempts to jump, and the mean was considered as the final measure [24].

Protocol Training during 14-Week in-season

The athletes were submitted to a training protocol of 14 weeks, with a weekly volume between 6.5 hours to 10.8 hours. The works of in-season have focused on specific organic adaptations to improve performance in relation to levels of strength and endurance, key capabilities to sustain intense activities during the game. Thus, assessments of motor performance tests and cardiorespiratory profile are used to understand mechanisms of these adaptations across the training content. The training was classified into two types of activities: functional and neuromuscular. Functional training was related to general endurance, specific endurance, and speed endurance. Neuromuscular training included special strength, strength endurance, agility, maximum strength, and maximum speed [25]. The volume of the activities was 5562 and 1700 minutes, respectively. The table 2 indicates divisions, subdivisions, and percentage of the activities addressed.

Table 2. Training organization during 14-week in-season training

Energy System	Biomotor Capacity	Capacity Manifestation	Absolute (%)
Functional (5552 min)	Endurance	General Endurance	4.0
		Special Endurance	65.4
		Speed Endurance	7.2
		Total (%)	76.6
Neuromuscular (1700 min)	Strength Speed Agility	Special Strength	7.9
		Endurance Strength	6.3
		Maximum Strength	3.7
		Maximum Speed	1.1
		Agility	4.4
		Total (%)	23.4

Statistical Analysis

Data is presented as mean ± standard deviation for variables for sample characterization, the ventilatory parameters, heart rate and variable motor performance. Then was analyzed data normality pre-test and post-test by Shapiro-Wilk test. It was not observed normal distribution, the pre-test and posta-test data were comparison by Wilcoxon Rank-sum test for paired samples using. R-plus© statistical software version 2.14.0 was used. Significance level was adopted at $p \leq 0.05$.

4. Results

Cardiorespiratory profile of Paralympic 5-a-side football athletes from the Brazilian Paralympic team

The cardiorespiratory profile of these athletes was evaluated before and after 14-week in-season training, as described in the methodology. Table 3 shows their heart rate (HR) and oxygen uptake (VO_2) values at these two moments as measured. With the exception of VO_{2max}, the parameters of oxygen uptake and heart rate as ventilatory threshold as the respiratory compensation point was a trend towards lower values following the training period was a trend towards lower values following the training period. However, such differences were not statistically significant for HR, as well as the maximum HR ($\%HR_{max}^{VT}$) and oxygen uptake (VO_2^{VT}) at ventilatory threshold. Conversely, there was a significant difference in $\%HR_{max}$ and VO_2, when the intensity of physical effort reached the threshold between the stable state condition and the anaerobic zone (respiratory compensation point).

Table 3. Ergospirometry results (mean ± standard deviation) pre and post 14-week in-season training

Variables	Pre	Post
HR^{VT}(bpm)	162.7 (±9.4)	158.4 (±13.4)
HR^{RCP}(bpm)	182.4 (±8.1)	173.1 (±12.3)
% $HR_{max}{}^{VT}$	84.5 (±5.3)	82.2 (±5.0)
% $HR_{max}{}^{RCP}$	94.7 (±2.3)	89.9 (±3.7)*
HR_{max} (bpm)	192.5 (±9.4)	192.4 (±8.0)
$VO_2{}^{VT}$ mL(kg.min)$^{-1}$	37.9 (±5.2)	33.9 (±6.1)
$VO_2{}^{RCP}$ mL(kg.min)$^{-1}$	48.4 (±4.4)	41.1 (±6.8)*
VO_{2max} mL(kg.min)$^{-1}$	51.9 (±3.8)	54.3 (±5.5)

VT: Ventilatory Threshold; RCP: respiratory compensation point; HR: Heart Rate; %HRmax: Maximum Heart Rate Percentage; HRmax: Maximum Heart Rate; VO_2: Oxygen Uptake mL(kg.min)$^{-1}$; VO_{2max}: Maximum Oxygen Uptake mL(kg.min)$^{-1}$.
* denotes significant differences at p ≤0.05

Motor profile of Paralympic 5-a-side football elite athletes

The table 4 presents the motor performance of the athletes as measured by their anaerobic power, agility, and explosive strength before and after training.

Table 4. Motor results (mean ± standard deviation) pre and post 14-week in-season training

Variables	Pre	Post
PO_{peak} (W)	518.91 (± 87.77)	528.26 (± 87.15)
PO_{medium} (W)	411.73 (± 62.53)	421.94 (± 65.55)
PO_{min} (W)	320.76 (± 63.02)	324.53 (± 65.21)
FI (W/s)	63.10 (± 9.43)	53.90 (± 14.80)
AG (s)	22.20 (± 2.88)	22.50 (± 2.38)
SLJT (m)	2.16 (± 0.12)	2.18 (± 0.13)

PO_{peak}: Power Output Peak in Watts; PO_{medium}: Medium Power Output in Watts; PO_{min}: Minimum Power Output in Watts; FI – Fatigue Index in Watts per second; AG – Agility in seconds; SLJT – Standing Long Jump Test in meters.
* denotes significant differences at p ≤ 0.05

The variables described enable the analysis of the ability to perform short-duration and high-intensity moves, and the corresponding muscle recovery. Even though the results do not show significant differences between the pre and post-test, there was a trend towards higher values after training for those variables measuring anaerobic parameters PO_{peak}, PO_{medium}, PO_{min}. The FI was an exception to this trend.

5. Discussion

Overall, our results show that while the performance of these athletes is inferior to that of professional players, their cardiorespiratory and motor performance is superior to that typical of semi-professional futsal athletes.

The cardiorespiratory tests showed that both before and after 14-week in-season training, VO_{2max} in these Paralympic athletes was lower than that of professional indoor soccer players [8-10], and similar to that of semi-professional Italian indoor soccer players [10]. Considering that maximum oxygen uptake is an indicator of the maximum limit of aerobic exercise tolerance [26], our results suggest that visually impaired athletes are less tolerant (lower VO_{2max}) to this type of activity than non-disabled indoor soccer athletes, but have a tolerance similar to that of semi-professional athletes. Although $VO2^{RCP}$ and HR^{RCP} pre-training values were higher than those of indoor professional athletes [10, 9], they were lower after training. On average, $VO_2{}^{RCP}$ of our study population was inferior to that of professional athletes [8] but superior compared to semi-professional athletes [10]. The RCP (respiratory compensation point) is the peak moment where exercise intensity requires mainly aerobic metabolism for energy supply [27]. Above this level, metabolic processes will favor fatigue onset [26]. Our findings indicate that Paralympic 5-a-side football athletes have a faster fatigue onset than professional athletes, and slower fatigue onset than semi-professional athletes, as exercise intensity increases.

It is worth noticing that in our study we did not observe a significant decrease in the cardiorespiratory parameters with the exception of $\%HR_{max}$ and VO_2 in the RCP post-training. This significant decrease, which is indicative of an earlier onset of fatigue as exercise intensity increases, might be related to the interference of increases of the contents specifics training (functional activities). Most of the technical-tactical actions performed were game-related considering volume and intensity, factors that contribute to remodeling the cardiorespiratory aspect, specially of the RCP, once this modality presents few moves of high intensity regarding the game duration. However, the latter possibilities were not evaluated, suggesting future studies about this modality characterization for a better comprehension of these factors.

In terms of motor performance, PO_{max} and PO_{medium} were less than those of non-disabled indoor soccer athletes [8]. PO_{max} is related to sprint performance (maximal speed), whereas PO_{medium} symbolizes the ability to endure anaerobic activity for prolonged periods (speed endurance). Therefore, our results indicate that visually impaired athletes show slower speed in sprints, as well as a lower tolerance for anaerobic activities. The higher FI observed, as compared to professional athletes, supports this finding [8].

In addition to the previously described parameters, we also characterized the athletes' profile through the Agility 5x10 [22] and SLJT [24] tests. Agility is the ability underlying fast and efficient direction change. Its measurement is particularly important considering its direct influence in the improvement of strength, balance, speed and coordination [28].

Specifically, the SLJT characterizes performance levels of maximum strength/power in the long jump, which is widely analyzed in non-disabled soccer modality [29-31]. Maximum strength is typically defined as the result of muscle strength production in a specific movement, and is strongly associated with sprints and the distance reached in vertical jumps in soccer players [29, 32]. Maximum jump distances were within the average observed for athletes of non-disabled modalities [33].

[15] identified the alterations obtained in oxygen uptake during the period of pre-season in football 5-a-side. There was significant improvement in VO_{2max} of athletes in a period of 16 weeks, with the value of 44.7 ml(kg.min)$^{-1}$ before and 50.3 ml.(kg.min)$^{-1}$ after 16-week pre-season. In this study it was observed that athletes have higher levels of cardiorespiratory fitness during pre-training as in the post-training period although shorter training. Whereas the competitive level of the sport has been increasingly intense and demanding during the competition, the demand of effort associated with the training content may have been the key factors for increasing cardiorespiratory levels, causing the athlete support higher intensities game for a long period of time. Another discussion may be related to methodological differences between studies, since the study of [15] used the yo-yo test 20m, while the present study was developed by cardiopulmonary exercise testing laboratory. For parameters of anaerobic capacity and power, it was observed that, in this study, the levels of maximum power and fatigue index were superior, while the PO_{min} and PO_{med} levels were lower. Although the differences observed in both studies was improvement in absolute values, but more studies should be developed in an attempt to establish a normative standard for elite athlete in the sport. In this way, the previous comparisons with non-disabled soccer athletes were favored based on the similarity between both modalities in terms of rules and game dynamism. The observed differences in the physiological characteristics of athletes between these two modalities might be due to the difficulty experienced by visually impaired athletes in performing technical tasks. In addition, activities that require maximum speed or strength become compromised in 5-a-side football players, precluding the achievement of high levels of motor and cardiorespiratory performance.

It is important to consider that the small sample size may have influenced our ability to detect significant differences when comparing pre and post-training values. However, we believe that this aspect might have been minimized by the high training level of the athletes included in this study.

6. Conclusions

Overall, our results show that while the performance of Brazilian Paralympic Team athletes is inferior to that of professional players, their cardiorespiratory and motor performance is superior to that typical of semi-professional futsal athletes. Furthermore, the identification of the physiological and motor profile of elite athletes in different modalities may be used as a reference model for the design and planning of training programs, and for guiding coaches and teams towards the achievement of the same training conditions of this paper. Within this context, Brazil is a country that shows success in this modality in the international scenario, holding titles in the main tournaments of the last two Paralympic cycles. Knowledge about the profile of these athletes is in this regard essential to make it possible for coaches to compare different periods of training.

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