

Behavior of maximum aerobic capacity of young handball athletes from Rio de Janeiro during the 2023 season

Comportamento da capacidade aeróbica máxima durante a temporada/2023 de jovens atletas de handebol do Rio de Janeiro

Pablo Rodrigo de Oliveira Silva^{1,2} , Ricardo Gonçalves Cordeiro^{3,4,5} ,
Emanuel Clemente de Oliveira² , Juliana de Alcantara Silva Fonseca¹ 

1. Universidade Castelo Branco, Rio de Janeiro, RJ, Brazil

2. Centro Universitário São José, Rio de Janeiro, RJ, Brazil

3. Universidade do Estado do Rio de Janeiro, Rio de Janeiro, RJ, Brazil

4. Centro Universitário Augusto Motta, Rio de Janeiro, RJ, Brazil

5. Universidade Estácio de Sá, Rio de Janeiro, RJ, Brazil

ABSTRACT

Introduction: Maximum aerobic capacity (VO_{2max}) is essential for handball performance, as it participates in the aerobic metabolism that acts on the alternation of stimuli that this modality requires. However, few studies in the literature investigated VO_{2max} throughout the periodization, especially in young athletes. **Aime:** This study aimed to analyze VO_{2max} behavior during a competitive season of a women's handball team. **Methods:** During 41 weeks (microcycles), young female handball athletes from Clube Esportivo Suzano Costa – (CESC-RJ) (n: 21; 16.8 ± 0.7 years; 66.8 ± 8.7 kg; 167.0 ± 0.07 cm; 24.0 ± 2.0 kg/m²) performed the Yo-Yo intermittent recovery level 1 field test (YoYo IR1) at 4-time points: before microcycle 1, at the end of microcycle 8 of the pre-season, in the middle of microcycle 24 and near the end of microcycle 39 of the competitive period. VO_{2max} behavior was analyzed with one-way repeated measures ANOVA, followed by Bonferroni's post hoc test. The probability level was set at $p < 0.05$. **Results:** Significant increase in VO_{2max} was observed ($F = 16.2$; $p < 0.0001$; post hoc = $p < 0.05$) between moments 1 (45.1 ± 3.4 mL.kg⁻¹.min⁻¹) vs. 2, 3 and 4 (50.7 ± 3.7 vs. 51.1 ± 3.0 vs. 50.6 ± 3.0 mL.kg⁻¹.min⁻¹, respectively). **Conclusion:** It was possible to verify the increase in VO_{2max} after the pre-season and its maintenance in young handball athletes during the 2023 season.

Keywords: athletes; VO_{2max} ; handball; high performance.

RESUMO

Introdução: A capacidade aeróbica máxima (VO_{2max}) é essencial para o desempenho no handebol, pois participa do metabolismo aeróbico que atua nas alternâncias de estímulos que essa modalidade exige. No entanto, poucos estudos na literatura investigaram o VO_{2max} ao longo da periodização, principalmente em atletas jovens. **Objetivo:** Este estudo teve como objetivo analisar o comportamento do VO_{2max} durante uma temporada competitiva de uma equipe feminina de handebol. **Métodos:** Durante 41 semanas (microciclos), atletas jovens de handebol do Clube Esportivo Suzano Costa – (CESC-RJ) (n: 21; $16,8 \pm 0,7$ anos; $66,8 \pm 8,7$ kg; $167,0 \pm 0,07$ cm; $24,0 \pm 2,0$ kg/m²) realizaram o teste de campo Yo-Yo intermitente de recuperação nível 1 (YoYo IR1) em 4 momentos: antes do microciclo 1, no final do microciclo 8 da pré-temporada, no meio do microciclo 24 e próximo ao final do microciclo 39 do período competitivo. O comportamento do VO_{2max} foi analisado por meio de ANOVA de medidas repetidas unidirecional, seguido do teste post hoc de Bonferroni. O nível de probabilidade foi estabelecido em $p < 0,05$. **Resultados:** Foi observado aumento significativo do VO_{2max} ($F = 16,2$; $p < 0,0001$; post hoc = $p < 0,05$) entre os momentos 1 ($45,1 \pm 3,4$ mL.kg⁻¹.min⁻¹) vs. 2, 3 e 4 ($50,7 \pm 3,7$ vs. $51,1 \pm 3,0$ vs. $50,6 \pm 3,0$ mL.kg⁻¹.min⁻¹, respectivamente). **Conclusão:** Foi possível verificar o aumento do VO_{2max} após a pré-temporada e sua manutenção em jovens atletas de handebol durante a temporada de 2023.

Palavras-chave: atletas; VO_{2max} ; handebol; alto rendimento.

Introduction

Handball is a sport modality that encompasses several physical capacities such as agility, explosive strength, anaerobic power and endurance, displacement speed, reaction speed and aerobic endurance [1]. Póvoas *et al.* [2] report that aerobic metabolism is the most predominant in the sport, which is characterized by alternating high-intensity stimuli with recovery periods.

The best indicator of aerobic capacity is maximum oxygen consumption ($\text{VO}_{2\text{max}}$), as it reflects the maximum volume of oxygen that the body captures, transports and uses [3]. The higher the $\text{VO}_{2\text{max}}$, the greater the aerobic conditioning of an individual [4]. Studies show that a highly developed aerobic capacity appears to be important for reducing cardiocirculatory demands and optimizing performance during handball matches [5,6].

During the sports season, physical capacities may vary in their performance [7,8]. Periodization is the process of organizing physical capacities and workloads during a season. Through periodization, it is possible to program periods or training sessions to acquire performance or for the athlete's recovery. There are different periodization models, with the classic, in blocks, by selective loads and self-structured microcycles standing out [9-11].

Scientific studies involving young athletes and in most female sports are scarce in randomized and controlled studies, especially regarding maximum aerobic capacity. As far as we know, few studies clearly explain how the dynamics of physical qualities occur during a competitive handball season. Some studies have demonstrated significant increases in $\text{VO}_{2\text{max}}$ over a period of physical training in professional handball competitions [2,12]. It is worth noting that different types of training periodization (traditional vs. block) provide similar effects with significant increases in $\text{VO}_{2\text{max}}$ in elite athletes from the Spanish first division [12]. $\text{VO}_{2\text{max}}$ is one of the fundamental variables for outlining the aerobic fitness profile of each playing position, to understand the health status and monitor the athlete's performance. Therefore, understanding how $\text{VO}_{2\text{max}}$ behaves during a season under the effects of physical training becomes important, since through this monitoring, coaches and physical trainers can prescribe more effective training and monitor the adaptations that occur [13].

Considering the above, the objective of the study was to analyze the behavior of $\text{VO}_{2\text{max}}$ during a follow-up in the 2023 season of the youth category (athletes up to 18 years of age) of a handball team.

Methods

Participant characterization

Twenty-one female individuals participated in the study. All were national-level handball athletes from the same team. Some athletes had played for Brazilian cadet and youth teams. The athletes trained five times a week, totaling 12 hours of weekly training. This study was approved by the ethics committee of the Augusto Motta University Center (CAAE: 55815522.7.0000.5235), and the research followed the guidelines of Resolution 466/12 of the National Health Council. All the athletes' guardians gave their written informed consent before participation.

Inclusion and exclusion criteria

Female athletes aged between 15 and 18 years with medical clearance to practice physical exercises were included. The athletes had to have participated in official competitions for at least one year. Athletes whose parents or guardians did not authorize them did not participate in the study.

Procedures

A cohort study was conducted to collect information about the anthropometric profile and the yoyo intermittent recovery level 1 (Yoyo IR1) test. The assessments were performed at the athletes' training site.

The season consisted of 41 weeks (microcycles). Assessments were performed 4 times: at the beginning (microcycle 1) and at the end (microcycle 8) of the pre-season, in the middle (microcycle 24) and near the end (microcycle 39) of the competitive period. A periodization model with selective loads similar to that of the study by Thiengo *et al.* [14] was used. In this type of periodization, there is an alternation in the emphasis on physical capacities; that is, several physical capacities are worked on during the week. However, there is an emphasis on one or two physical capacities in this microcycle.

Total body mass was measured on a scale (FILIZOLA; maximum capacity = 300 kg; accuracy = 100 g). All participants were instructed to wear light clothing and be barefoot during measurement. Height was measured on a scale with a stadiometer (FILIZOLA, 0.01 cm, São Paulo, Brazil). The height of the individual was given by the distance from the sole to the apex of the head (vertex point). The formula for calculating BMI was: $BMI = \text{Total Body Mass} / \text{Height}^2$. The values are shown in Table I.

Table I – Characterization of the sample

Variable	Result
Age (years)	16.8 ± 0.7
TBM (kg)	66.8 ± 8.7
Estatute (m)	1.67 ± 0.07
IMC (kg/m ²)	24.0 ± 2.0

TBM – total body mass; BMI – body mass index

VO_{2max} was indirectly predicted by the Yo-Yo Intermittent Recovery Test Level 1 (Yo-yo IR1) [15]. The test completed a previously marked 20-meter course with a five-meter rest area. The Yo-yo IR1 was paced by sound signals, which progressively increased in volume. This protocol is described and recorded in an audio file. To begin the test, the athlete moved from one mark to the other (20 meters one way) and then back (another 20 meters); upon completing this course, he or she had a 10-s rest. The speed, determined by the rhythm of the audio, was progressively increased at each stage, and the athlete had to reach the other point before the sound signal, which indicated that the test should restart. The test was terminated when the athlete failed to reach two marks in a row or could not move due to physical fatigue. The person evaluated performed the most significant number of movements within the sound stimulus protocol, with VO_{2max} estimated based on the total distance traveled by the athlete, using the formula:

$$VO_{2max} \text{ (mL.kg}^{-1}\text{.min}^{-1}\text{)} = ((\text{distance traveled (meters)} \times 0.0084) + 36.4)$$

Statistical analysis

The normality of the data was verified using the Shapiro-Wilk test, and the data are expressed as mean and standard deviation. The ANOVA test for repeated measures was used to identify significant differences between the measurements taken in the different periods, and the probability level was set at $p < 0.05$. When a significant difference was found, the Bonferroni post-hoc test was used to verify between which assessments these differences occurred. The results were analyzed using the SPSS statistical program (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.).

Results

Twenty-one athletes were recruited. One athlete was lost to injury during the season and did not participate in the last assessment. Among the group analyzed, they played in different positions (3 goalkeepers, 8 point guards, five forwards, and five pivots).

Table II shows the data (mean ± standard deviation) regarding the assessments performed during the season. Significant differences in VO_{2max} were observed

when comparing the last three assessments with the first. The differences (Δ) between the assessments (subtraction between each assessment 2, 3, 4, and assessment 1) were approximately $\sim\Delta$ 5.6 mL.kg⁻¹.min⁻¹, $\sim\Delta$ 6.0 mL.kg⁻¹.min⁻¹ and $\sim\Delta$ 5.5 mL.kg⁻¹.min⁻¹.

There were statistically significant differences in VO_{2max} and distance covered between the first and the other evaluations. Regarding the distance covered in the test, there was a statistically significant difference between the first and the other evaluations ($p < 0.05$). The F value was 16.2 ($p < 0.001$; post hoc = $p < 0.05$) for VO_{2max} and 21.2 ($p < 0.001$; post hoc = $p < 0.05$) for the distance covered.

Table II – Changes in predicted maximum oxygen consumption and distance covered in the Yo-Yo Intermittent Recovery Test Level 1 during the season. p values represent the difference between Assessment 1 and the others

	VO_{2max} (mL.kg ⁻¹ .min ⁻¹)	p	Distance covered (metros)	p
Assessment 1	45.1 $\pm$ 3.4		1035.2 $\pm$ 403.8	
Assessment 2	50.7 $\pm$ 3.7	0.4	1701.0 $\pm$ 441.1	0.4
Assessment 3	51.1 $\pm$ 3.0	0.3	1752.4 $\pm$ 350.3	0.3
Assessment 4	50.6 $\pm$ 3.0	0.3	1698.1 $\pm$ 355.2	0.3

Discussion

This study aimed to observe changes in maximum oxygen consumption by the intermittent YoYo test throughout a season in a female handball team in the youth category. A significant increase in VO_{2max} was observed during the season when compared with pre-season data (baseline).

During the competitive period, the VO_{2max} (in mL.kg⁻¹.min⁻¹) values of the athletes in this study were similar to the athletes in the Danish league [4]. The VO_{2max} of the Danish athletes was 49.6 $\pm$ 4.8, while the average values of the athletes in our study ranged from 50.6 to 51.1. The VO_{2max} in adult Uruguayan athletes was 35.0 $\pm$ 4.4 [16], values lower than those of the athletes in this study. During a season, the annual training cycle or periodization can be divided into a preparatory period or pre-season, a competitive period, and a transition period. The pre-season aims to create adaptations so that the athlete is ready to perform better during the competition. At the beginning of the pre-season, athletes tend to come from a transition period, the objective of which is to rest the athlete from the previous season [17].

The lower VO_{2max} values, which are statistically significant in relation to the rest of the season, can be explained by the transition period since the team has not trained for at least 8 weeks since the end of the previous season. During the pre-season, workloads are gradually increased so that the athlete can create adaptations and have optimal performance in the sport's essential physical capacities [18].

During the competitive period, the objective of periodization in sports is for the athlete to maintain their physical capacities at optimal levels so that they can

perform during the different competitions of the season [19]. It is common in team sports for some competitions to last for a long period, more than two months. It is also common for a team to participate in two or more competitions at the same time.

In the present study, there was no statistically significant difference in the estimated $\text{VO}_{2\text{max}}$ at the end of the pre-season and during the two assessments carried out during the competitive period. This shows that the $\text{VO}_{2\text{max}}$ remained stable during this time interval. It is interesting to note that during this period, the aerobic capacity of the athletes was close to that of athletes from European teams, $49.6 \pm 4.8 \text{ mL.kg}^{-1}.\text{min}^{-1}$ [4], which are the greatest powerhouses in the sport.

$\text{VO}_{2\text{max}}$ is a physiological characteristic limited by the parametric limits of the Fick equation: (left ventricular (LV) end-diastolic volume – LV end-systolic volume) $\times$ heart rate $\times$ arteriovenous oxygen difference) [20]. The “classical” views of $\text{VO}_{2\text{max}}$ emphasize its critical dependence on oxygen transport to functioning skeletal muscle, and this cardiopulmonary mechanism is improved by exercise training mainly by improving the diffusion of hematoalveolar capacity, pulmonary capillary blood volume, and pulmonary nitric oxide diffusion [21].

Furthermore, exercise training has been shown to improve red blood cell expansion associated with increased cardiac output in correlation with increased stroke volume, as followed by enlargement of the ventricular chambers with increased myocardium along with its compliance, facilitating end-diastolic volume and stroke volume [22]. “Contemporary” investigations into the mechanisms underlying peripheral muscle fatigue due to the mismatch between energy supply and demand are clarifying the local mediators of fatigue at the skeletal muscle level, through the afferent signaling pathways that communicate these environmental conditions to the brain and the central brain integration sites [23,24]. This mechanism can be explained by the decrease in oxygen in the prefrontal cortex simultaneously with the decrease in systolic volume, which will decrease the supply of muscle oxygen [25]. However, the improvement in neuromotor control associated with the cardiovascular system with physical training still requires further investigation [26].

Elite athletes have high $\text{VO}_{2\text{max}}$ due primarily to high cardiac output from a large compliant cardiac chamber (including the myocardium and pericardium) that relaxes rapidly and fills a large end-diastolic volume. This large left ventricular filling and ejection capacity allows blood pressure to be preserved at extraordinary rates during muscle blood flow and oxygen transport, which support high rates of sustained oxidative metabolism [20]. The increase in $\text{VO}_{2\text{max}}$ with training in handball athletes is controversial; one study demonstrated no significant increases during a training period [27], while another demonstrated a significant increase in maximal aerobic power due to increased ventricular mass, thus contributing to the cardiovascular mechanisms that increase $\text{VO}_{2\text{MAX}}$ [28].

Improving $\text{VO}_{2\text{max}}$ for handball athletes is directly associated with improved performance, as demonstrated by Manchado *et al.* [6] with athletes from the first division of the German league, with an average age of 25.2 ± 2.8 years. The authors

observed a direct association between performance and $\text{VO}_{2\text{max}}$ in those with the highest performance. The study assessed the movement pattern, including the acceleration profile of sprints during league games.

One of the study's limitations is that aerobic capacity assessments were not performed at the end of each mesocycle, as this would have allowed for better verification of $\text{VO}_{2\text{max}}$ fluctuations. However, due to the competitive calendar, performing four aerobic capacity assessments during the season is unprecedented in research on handball athletes in the youth categories.

Practical applications

Considering that handball is a sport with a predominance of aerobic activity, knowing the physiological characteristics of athletes is essential for monitoring their sports performance during a season. Aerobic capacity is important for the game's development since low values of this physical valence can negatively influence the athlete's performance.

Understanding the fluctuations in physical capacities during the season becomes essential for preparing an annual plan. These fluctuations will occur during a macrocycle. With $\text{VO}_{2\text{max}}$ values, it is possible to prepare more assertive prescriptions and monitor each athlete's progress individually. For the development of high-performance handball, physical capacities such as agility, explosive strength, and repeated sprinting skills are essential for performance.

Conclusion

Handball is a sport with intermittent characteristics, alternating high- and low-intensity stimuli, and a predominance of aerobic metabolism. The present study found that at the beginning of the season, $\text{VO}_{2\text{max}}$ is lower than in other training phases. After 8 weeks of training through selective load-guided periodization, $\text{VO}_{2\text{max}}$ increases significantly, with no differences throughout the season. Further studies are needed to fully describe and compare aerobic adaptations during the season and assessments related to different physical capacities.

Conflict of interest

The authors declare no conflict of interest.

Sources of funding

The authors declare that they have not received funding.

Author's contribution

Conception and design of the research: Silva PRO; **Data collection:** Silva PRO, Oliveira EC, Fonseca JAS; **Análise e interpretação dos dados:** Silva PRO, Cordeiro RG; **Statistical analysis:** Silva PRO, Cordeiro RG; **Manuscript writing:** Silva PRO, Oliveira EC, Fonseca JAS; **Critical revision of the manuscript for important intellectual content:** Silva PRO, Cordeiro RG

References

1. Charron J, Garcia JEV, Roy P, Ferland P-M, Comtois AS. Physiological responses to repeated running sprint ability tests: a systematic review. *International journal of exercise science* [Internet]. 2020;13(4):1190–205. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/33042370> <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC7523911>
2. Póvoas SCA, Castagna C, Resende C, Coelho EF, Silva P, Santos R, et al. Physical and physiological demands of recreational team handball for adult untrained men. *BioMed Research International*. 2017;2017:6204603. doi: 10.1155/2017/6204603.
3. Wasserman K, Hansen JE, Sue DY, Casaburi R, Whipp BJ. *Principles of Exercise Test and Interpretation*. 4th ed. Baltimore: Lippincott Williams & Wilkins; 2004.
4. Michalsik LB, Aagaard P. Physical demands in elite team handball: Comparisons between male and female players. *J Sports Med Phys Fitness*. 2015;55(9):878–91.
5. Povoas SCA, Seabra AFT, Ascensão ANAMR, Magalhães J, Soares JMC, Rebelo ANNC. Physical and physiological demands of elite team handball. *J Strength Cond Res*. 2012;26(12):3365–75. doi: 10.1519/JSC.0b013e318248aeec
6. Manchado C, Pers J, Navarro F, Han A, Sung E, Platen P. Time-motion analysis in women's team handball: Importance of aerobic performance. *Journal of Human Sport and Exercise*. 2013;8(2suppl):376–90. doi: 10.4100/jhse.2012.82.06
7. Silva JR. The soccer season: performance variations and evolutionary trends. *Peer J*. 2022;10. doi: 10.7717/peerj.14082. eCollection 2022
8. Alves J, Barrientos G, Toro V, Sánchez E, Muñoz D, Maynar M. Changes in anthropometric and performance parameters in high-level endurance athletes during a sports season. *Int J Environ Res Public Health*. 2021 Mar 9;18(5):2782. doi: 10.3390/ijerph18052782
9. Kataoka R, Vasenina E, Loenneke J, Buckner SL. Periodization: Variation in the Definition and Discrepancies in Study Design. *Sports Med*. 2021;51(4):625–51. doi: 10.1007/s40279-020-01414-5
10. Kiely J. Periodization Theory: Confronting an Inconvenient Truth. *Sports Med*. 2018;48(4):753–64. doi: 10.1007/s40279-017-0823-y
11. Alcalá EP, Garcia AM, Trench MG, Hernández IG, Tarragó i Costa JR, Vargas FS, et al. Training in team sports: Optimising training at FCB. *Apunts Educacion Fisica y Deportes*. 2020;(142):55–66.
12. Manchado C, Cortell-Tormo JM, Tortosa-Martínez J. Effects of two different training periodization models on physical and physiological aspects of elite female team handball players. *J Strength Cond Res*. 2018 Jan;32(1):280–287. doi: 10.1519/JSC.0000000000002259
13. Ilic V, Ranisavljev I, Stefanovic D, Ivanovic V, Mrdakovic V. Impact of body composition and VO₂max on the competitive success in top-level handball players. *Coll Antropol*. 2015;39(3):535–40.
14. Thiengo CR, Talamoni GA, Da Silva RNB, Dos Santos Morceli H, Porfírio JC, Dos-Santos JW. Efeito do modelo de periodização com cargas seletivas sobre capacidades motoras durante um mesociclo preparatório em jogadores de futsal. *Rev Bras Cienc Esporte*. 2013;35(4):1035–50. doi: 10.1590/S0101-32892013000400015
15. Bangsbo J, Iaia M, Krustu P. The Yo-Yo intermittent recovery test: a useful tool for evaluation of physical performance in intermittent sports. *Sports Med*. 2008;38(1):37–51. doi: 10.2165/00007256-200838010-00004
16. Parodi-Feye AS, Cappuccio-Díaz ÁD, Magallanes-Mira CA. Effects of inspiratory muscle training on physiological performance variables in women's handball. *J Human Kinet*. 2023;89:101–12. doi: 10.5114/jhk/169366
17. Purdom TM, Levers KS, Ryan GA, Brown L, Giles J, McPherson C. Female soccer periodization on anaerobic power/capacity. *J Strength Cond Res*. 2023;37(12):2405–10.
18. Bressan T, De Wit P, Venera GD., Cruz RM., Nunes EA., Rocha RER. Efeito da periodização de cargas seletivas no desempenho físico e parâmetros hematológicos em jogadores de handball. *Revista Brasileira de Prescrição e Fisiologia do Exercício*. 2019;13(84):642–51.
19. Borin JP, Gomes AC, Leite GS. Sporting preparation: Aspects of load training control in collective games. *Journal of Physical Education*. 2007;18(2):97–105.
20. Levine BD. VO₂: What do we know, and what do we still need to know? *J Physiol*. 2008;586(1):25–34. doi: 10.1113/jphysiol.2007.147629

