

## A Descriptive Analysis of Aerobic Capacity and Ventilatory Responses in Professional Football Players According to Playing Position

LUCAS FULLI DO NASCIMENTO MANHÃES<sup>1</sup>  
SABINO SALES DE OLIVEIRA JÚNIOR  
ANDERSON TAVARES SILVA  
LUIZ FELIPE DA CRUZ RANGEL  
ANDERSON PONTES MORALES

*Laboratory of Applied Physiology to Health, Performance, and Physical Education  
Higher Institutes of Education of CENSA (ISECENSA)  
Rua Voluntários da Pátria, 230, Campos dos Goytacazes, RJ, 28035-310, Brazil*

### Abstract

*The present study aimed to analyze the aerobic capacity of professional football players according to their playing positions using a maximal ventilometry test on a treadmill. A total of 20 professional male players were evaluated and grouped by position (attackers, midfielders, defenders, full-backs, and goalkeepers). The variables analyzed included maximal oxygen uptake ( $VO_{2max}$ ), maximal heart rate ( $HR_{max}$ ), maximal ventilation ( $VE$ ), running speed, ventilatory thresholds ( $LV1$  and  $LV2$ ), energy expenditure, and body composition. Data were analyzed using descriptive statistics and are presented as mean  $\pm$  standard deviation. The results showed variations among playing positions. Full-backs and attackers presented higher  $VO_{2max}$  values and maximal speeds, suggesting greater aerobic capacity and performance. Midfielders demonstrated intermediate values, while defenders showed slightly higher ventilatory responses. Goalkeepers presented lower values in most variables, reflecting the specific physiological demands of the position. Ventilatory thresholds were relatively similar across positions. In conclusion, the results suggest positional differences in aerobic capacity and ventilatory responses in professional football players. These findings reinforce the importance of individualized physiological assessment and position-specific training strategies to optimize performance and physical conditioning.*

**Keywords:** football; aerobic capacity; ventilatory thresholds;  $VO_{2max}$ ; exercise physiology; performance

### INTRODUCTION

Football is a high-intensity intermittent sport that requires players to perform repeated bouts of sprinting, accelerations, decelerations, and changes of direction throughout prolonged match durations. Although decisive actions are predominantly anaerobic, the aerobic system plays a fundamental role in sustaining performance and facilitating recovery between high-intensity efforts. Classic studies have demonstrated that professional football players cover approximately 10 km during a match, with a

---

<sup>1</sup> Lucas Fulli do Nascimento Manhães is a researcher in exercise physiology with a focus on aerobic capacity and sports performance in football. His work is associated with the Laboratory of Applied Physiology to Health, Performance, and Physical Education at ISECENSA. His research interests include cardiopulmonary testing, ventilatory thresholds, and applied sports science. **Corresponding author**

substantial portion performed at intensities close to the anaerobic threshold, highlighting the importance of aerobic fitness in this sport (Stølen et al., 2005; Bangsbo, Mohr, & Krstrup, 2006).

Aerobic capacity is commonly assessed through maximal oxygen uptake ( $\text{VO}_2\text{max}$ ), which is widely recognized as a key indicator of cardiovascular and metabolic efficiency during exercise. However,  $\text{VO}_2\text{max}$  alone does not fully explain performance in intermittent sports such as football. In this context, submaximal parameters, particularly ventilatory thresholds, have gained increasing relevance. These thresholds represent the transition from predominantly aerobic metabolism to increased anaerobic contribution, characterized by a disproportionate increase in ventilation relative to oxygen consumption (Wasserman et al., 1973). Therefore, ventilatory thresholds provide a more functional assessment of exercise tolerance and performance capacity.

The identification of ventilatory thresholds through gas exchange analysis has become a central component in exercise physiology. The V-slope method proposed by Beaver, Wasserman, and Whipp (1986) allows for a non-invasive and reliable determination of these thresholds during incremental exercise. Such methods enable a detailed understanding of metabolic and ventilatory responses, contributing to more precise training prescription and performance evaluation.

Cardiopulmonary exercise testing (CPET) combined with ventilatory analysis is considered the gold standard for assessing aerobic capacity and integrative physiological responses to exercise. This approach allows simultaneous evaluation of cardiovascular, respiratory, and metabolic systems, providing comprehensive insights into exercise limitations and adaptations. In addition, CPET-derived variables have been widely used in both clinical and sports settings to guide exercise prescription and monitor training effects (Balady et al., 2010; Guazzi et al., 2012).

In football, aerobic and ventilatory parameters are particularly relevant due to the sport's intermittent nature and high physical demands. Previous studies have demonstrated that endurance-related variables differ according to playing positions and tactical roles, with midfield players generally presenting higher aerobic demands due to greater involvement in both offensive and defensive actions (Stølen et al., 2005; Bangsbo, Mohr, & Krstrup, 2006). Furthermore, differences in aerobic performance and ventilatory responses have been reported between playing positions and competitive levels, reinforcing the importance of individualized physiological assessment in professional football (Altmann et al., 2020; Helgerud et al., 2001).

In addition to positional differences, training interventions have shown that improvements in aerobic capacity can significantly enhance football performance. High-intensity aerobic training has been associated with increased  $\text{VO}_2\text{max}$ , improved running economy, and enhanced match performance indicators, such as distance covered and number of high-intensity actions (Helgerud et al., 2001; Iaia, Rampinini, & Bangsbo, 2009). These findings reinforce the practical importance of accurately assessing aerobic fitness in football players.

Despite the growing body of literature on football physiology, there remains a need for applied studies focusing on ventilatory responses in professional athletes using controlled laboratory protocols. The use of ventilometry during treadmill testing provides a detailed and objective assessment of aerobic capacity and ventilatory behavior, allowing a more precise characterization of physiological performance.

In this context, the present study, based on an original academic work, aimed to evaluate the aerobic capacity of professional football players using a maximal ventilometry test performed on a treadmill.

## **MATERIALS AND METHODS**

### **Experimental Design**

This study followed an observational, cross-sectional design aimed at evaluating the aerobic capacity of professional football players through ventilatory responses obtained during a maximal treadmill test. The study was developed from an applied sports physiology perspective, seeking to characterise aerobic and ventilatory parameters according to the positional roles performed by the athletes. The assessment was carried out under controlled conditions, allowing the collection of physiological, ventilatory, and performance-related variables during incremental exercise until maximal effort.

### **Sample**

The sample consisted of professional male football players regularly engaged in systematic training and competitive routines. The athletes were distributed according to their playing positions as attackers, goalkeepers, full-backs, midfielders, and defenders, allowing a positional analysis of the variables investigated. In total, the sample included seven attackers, one goalkeeper, two full-backs, eight midfielders, and two defenders. All participants were considered physically fit to perform maximal exercise testing and were informed about the assessment procedures before participation.

### **Materials**

The assessments were performed using a treadmill and a ventilometry system (VO<sub>2</sub> ProFitness - CEFISE Biotecnologia Esportiva, Nova Odessa, Brasil) for continuous monitoring of respiratory and ventilatory variables during exercise. The maximal cardiopulmonary exercise test was conducted using a progressive incremental protocol until voluntary exhaustion. Throughout the test, the main variables analysed included maximal oxygen uptake (VO<sub>2</sub>max), maximal heart rate, maximal ventilation (VE), energy expenditure, maximal running speed, speed corresponding to the first ventilatory threshold (LV1), heart rate at LV1, speed corresponding to the second ventilatory threshold (LV2), heart rate at LV2, body mass, and body fat percentage.

Ventilatory thresholds were determined from the ventilatory responses observed during the incremental protocol. The first ventilatory threshold was identified as the point at which ventilation started to increase disproportionately in relation to oxygen uptake, whereas the second ventilatory threshold represented a further marked increase in ventilation associated with greater metabolic stress and anaerobic contribution. These procedures are consistent with the physiological criteria traditionally described for ventilatory threshold identification.

### **Procedures**

The athletes underwent a maximal treadmill test using an incremental protocol designed to progressively increase exercise intensity until voluntary exhaustion. During the test, ventilatory and physiological variables were continuously monitored, enabling an integrated analysis of aerobic capacity and exercise responses. In addition to peak

responses, threshold-related variables were obtained in order to provide a more functional interpretation of aerobic performance.

The evaluation also included anthropometric and body composition variables, allowing a broader physiological characterisation of the sample. The data were subsequently organised according to playing position, making it possible to describe positional tendencies in aerobic capacity, ventilatory responses, and exercise performance.

### Statistical Analysis

The data were analyzed using descriptive statistics and are presented as mean  $\pm$  standard deviation according to playing position. This approach was adopted to characterize the physiological and ventilatory profiles of the athletes and to allow the comparison of trends between different positional groups. Considering the unequal number of athletes across positions, particularly the low representation of some groups, the results were interpreted descriptively, with emphasis on the practical behavior of the variables rather than on inferential comparisons.

## RESULTS

### Physiological and Performance Characteristics

The physiological, ventilatory, and performance variables according to playing position are presented in Table 1.

Overall, positional differences were observed across the analysed variables. Full-backs and attackers tended to present higher aerobic capacity, as indicated by greater VO<sub>2</sub>max values, while goalkeepers consistently showed lower values. Midfield players demonstrated intermediate results across most variables.

Maximal running speed and energy expenditure were also higher in full-backs, suggesting greater physical and metabolic demands associated with this position. In contrast, midfield players showed slightly lower maximal speeds despite representing the largest subgroup.

Regarding ventilatory responses, defenders and full-backs tended to present higher maximal ventilation values, while ventilatory thresholds showed relatively similar patterns across positions, with slight variations in speed and heart rate.

Body composition variables showed minimal variation between positions, indicating a relatively homogeneous profile among the athletes.

**Table 1. Physiological, ventilatory, and performance variables according to playing position (mean  $\pm$  SD).**

Variable	Attacker (n=7)	Goalkeeper (n=1)	Full-back (n=2)	Midfielder (n=8)	Defender (n=2)
Body mass (kg)	79.7 $\pm$ 9.2	85	78.5 $\pm$ 9.2	76.5 $\pm$ 6.7	88.0 $\pm$ 4.2
VO <sub>2</sub> max (ml $\cdot$ kg <sup>-1</sup> $\cdot$ min <sup>-1</sup> )	48.7 $\pm$ 3.5	44.3	51.4 $\pm$ 1.6	46.4 $\pm$ 2.2	46.4 $\pm$ 1.0
Max HR (bpm)	186.7 $\pm$ 6.5	183	190.5 $\pm$ 2.1	184.5 $\pm$ 7.6	187.5 $\pm$ 5.0
VE max (L $\cdot$ min <sup>-1</sup> )	137.1 $\pm$ 10.8	127.6	141.4 $\pm$ 8.6	135.5 $\pm$ 4.4	143.0 $\pm$ 3.2
Energy expenditure (kcal $\cdot$ min <sup>-1</sup> )	19.8 $\pm$ 2.1	18.5	21.3 $\pm$ 1.5	18.6 $\pm$ 1.7	20.4 $\pm$ 0.5
Max speed (km $\cdot$ h <sup>-1</sup> )	15.9 $\pm$ 0.7	14	16.5 $\pm$ 0.7	14.8 $\pm$ 0.9	15.5 $\pm$ 0.7
Speed at LV1 (km $\cdot$ h <sup>-1</sup> )	10.7 $\pm$ 0.5	10	11	10.1 $\pm$ 0.4	10.5 $\pm$ 0.7
HR at LV1 (bpm)	150.8 $\pm$ 6.1	145	152.5 $\pm$ 3.5	148.4 $\pm$ 5.3	150.5 $\pm$ 4.9
Speed at LV2 (km $\cdot$ h <sup>-1</sup> )	14.4 $\pm$ 0.8	13.5	14	13.8 $\pm$ 0.7	14.5 $\pm$ 0.7
HR at LV2 (bpm)	181.7 $\pm$ 6.3	179.4	185.0 $\pm$ 7.1	180.3 $\pm$ 5.6	183.0 $\pm$ 6.4
Body fat (%)	13.2 $\pm$ 1.3	13	13.4 $\pm$ 1.1	13.0 $\pm$ 1.4	13.3 $\pm$ 1.2

Values are presented as mean  $\pm$  standard deviation. VO<sub>2</sub>max = maximal oxygen uptake; HR = heart rate; VE = ventilation; LV1 = first ventilatory threshold; LV2 = second ventilatory threshold.

## DISCUSSION

The present study aimed to evaluate the aerobic capacity and ventilatory responses of professional football players using a maximal ventilometry test on a treadmill, with analysis according to playing position. The main findings indicate that positional differences exist in aerobic capacity, ventilatory variables, and performance-related parameters, with full-backs and attackers generally presenting higher values, while goalkeepers exhibited lower physiological responses across most variables.

The higher VO<sub>2</sub>max values observed in full-backs and attackers are consistent with the specific physical demands of these positions. Full-backs, in particular, are required to perform repeated high-intensity runs along the flanks, contributing both offensively and defensively, which increases their aerobic and anaerobic demands. Similarly, attackers frequently engage in sprinting actions and high-intensity movements. These findings are in agreement with previous studies demonstrating that positions involving greater total distance and high-intensity efforts tend to present higher aerobic capacity (Stølen et al., 2005; Bangsbo, Mohr, & Krstrup, 2006).

In contrast, goalkeepers showed lower VO<sub>2</sub>max and performance-related values, which can be explained by the distinct physiological demands of this position. Goalkeepers rely more on explosive movements, reaction time, and anaerobic actions rather than sustained running, resulting in lower aerobic requirements. This positional specificity has been well documented in the literature, reinforcing the need for differentiated physical preparation strategies (Altmann et al., 2020).

Midfield players, despite representing the largest group in this study, demonstrated intermediate aerobic values. This finding may initially appear contradictory, as midfielders are traditionally associated with higher aerobic demands due to their involvement across the entire field. However, variations in tactical roles, team strategies, and individual training status may influence these results. Additionally, the heterogeneity within the midfield position itself can contribute to variability in physiological responses.

Regarding ventilatory responses, defenders and full-backs tended to present higher maximal ventilation (VE) values, suggesting greater ventilatory demand during maximal effort. This may be associated with increased body mass, higher absolute workload, or specific physiological adaptations. Ventilatory thresholds (LV1 and LV2), however, showed relatively similar patterns across positions, indicating that despite differences in maximal capacity, submaximal physiological behaviour may be more homogeneous among professional players. This aligns with previous findings suggesting that ventilatory thresholds are closely related to training status and metabolic efficiency rather than solely positional role (Wasserman et al., 1973; Beaver, Wasserman, & Whipp, 1986).

Performance variables such as maximal running speed and speeds at ventilatory thresholds further reinforce the positional demands of football. Full-backs and attackers demonstrated higher maximal speeds, which is consistent with the requirement for repeated sprint ability and high-intensity running during matches. These findings support the relevance of integrating laboratory-based measures, such as

ventilometry, with sport-specific performance indicators for a more comprehensive evaluation of athletes.

The relatively small variation in body fat percentage across positions suggests a homogeneous body composition profile among professional players, which is expected in elite-level sport environments. This reinforces that performance differences observed are more likely related to functional and physiological adaptations rather than differences in body composition.

From a practical perspective, the results of this study highlight the importance of individualized assessment and training prescription in football. The identification of positional differences in aerobic capacity and ventilatory responses supports the need for tailored conditioning programs that consider the specific physiological demands of each role on the field. Additionally, the use of ventilometry provides a detailed and objective evaluation of aerobic performance, offering valuable information for training monitoring and performance optimization.

This study presents some limitations that should be considered. The unequal distribution of participants across positions, particularly the low number of goalkeepers, full-backs, and defenders, limits the generalization of the findings. Furthermore, the absence of inferential statistical analysis restricts the ability to determine significant differences between groups. Future studies should include larger and more balanced samples, as well as longitudinal designs, to better understand the impact of training and competition on ventilatory and aerobic adaptations in football players.

## CONCLUSION

The results showed variations in aerobic capacity, ventilatory responses, and physiological efficiency among playing positions in professional football. Full-backs and attackers presented higher values, reflecting greater demands for high-intensity running and recovery, whereas goalkeepers showed lower aerobic capacity due to the specific demands of their role. These findings are consistent with the objective of the study and reinforce the importance of position-specific assessment and individualised training to optimise performance in football players.

## REFERENCES

1. Altmann, S., Ringhof, S., Neumann, R., Woll, A., and Rumpf, M. C. 2020. "Validity and Reliability of Speed Tests Used in Soccer: A Systematic Review." *PLOS ONE* 15 (8): e0235751. <https://doi.org/10.1371/journal.pone.0235751>
2. Balady, G. J., Arena, R., Sietsema, K., Myers, J., Coke, L., Fletcher, G. F., Forman, D., Franklin, B., Guazzi, M., Gulati, M., Keteyian, S. J., Lavie, C. J., Macko, R., Mancini, D., and Milani, R. V. 2010. "Clinician's Guide to Cardiopulmonary Exercise Testing in Adults." *Circulation* 122 (2): 191–225. <https://doi.org/10.1161/CIRCULATIONAHA.109.192520>
3. Bangsbo, J., Mohr, M., and Krstrup, P. 2006. "Physical and Metabolic Demands of Training and Match-Play in the Elite Football Player." *Journal of Sports Sciences* 24 (7): 665–674. <https://doi.org/10.1080/02640410500482529>
4. Beaver, W. L., Wasserman, K., and Whipp, B. J. 1986. "A New Method for Detecting Anaerobic Threshold by Gas Exchange." *Journal of Applied Physiology* 60 (6): 2020–2027. <https://doi.org/10.1152/jappl.1986.60.6.2020>
5. Guazzi, M., Adams, V., Conraads, V., Halle, M., Mezzani, A., Vanhees, L., Arena, R., Fletcher, G. F., Forman, D. E., Kitzman, D. W., Lavie, C. J., and Myers, J. 2012. "EACPR/AHA Scientific

- Statement: Clinical Recommendations for Cardiopulmonary Exercise Testing Data Assessment in Specific Patient Populations.” *European Heart Journal* 33 (23): 2917–2927. <https://doi.org/10.1093/eurheartj/ehs221>
6. Helgerud, J., Engen, L. C., Wisløff, U., and Hoff, J. 2001. “Aerobic Endurance Training Improves Soccer Performance.” *Medicine & Science in Sports & Exercise* 33 (11): 1925–1931. <https://doi.org/10.1097/00005768-200111000-00019>
  7. Iaia, F. M., Rampinini, E., and Bangsbo, J. 2009. “High-Intensity Training in Football.” *International Journal of Sports Physiology and Performance* 4 (3): 291–306. <https://doi.org/10.1123/ijsp.4.3.291>
  8. Stølen, T., Chamari, K., Castagna, C., and Wisløff, U. 2005. “Physiology of Soccer: An Update.” *Sports Medicine* 35 (6): 501–536. <https://doi.org/10.2165/00007256-200535060-00004>
  9. Wasserman, K., Whipp, B. J., Koyl, S. N., and Beaver, W. L. 1973. “Anaerobic Threshold and Respiratory Gas Exchange During Exercise.” *Journal of Applied Physiology* 35 (2): 236–243. <https://doi.org/10.1152/jappl.1973.35.2.236>