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Brief Report

Aerobic Power and Capacity in Highly Trained National-Level Youth Soccer Players Through On-Field Gas Exchange Assessment in an Ecological Context: A Brief Report

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Abstract: Background: Extensive data exists on external load during training and competition, but a significant gap remains in understanding internal physiological load, particularly in protocols conducted in ecological settings. Given the scarcity of studies on the on-field cardiorespiratory profiles of national-level athletes, especially in Argentine soccer, this study aimed to identify the on-field cardiorespiratory fitness profile of ten highly trained youth field soccer players (13.6 ± 1.3 years old) from both the first league of the Argentine Football Association and members of the national team in their age group category in the current year. Methods: Each athlete performed an on-field cardiorespiratory exercise test (20-m Shuttle Run Test, 20-m SRT) with the COSMED K5 wearable metabolic system (COSMED, Rome, Italy) in dynamic micro-mixing chamber mode. The 20-m Shuttle Run Test involves running back and forth between two lines set 20 m apart, following the pace set by an audio signal. The test starts at a running velocity of 8.5 km·h^{-1} and increases by 0.5 km·h^{-1} each min. Results: Mean velocity at maximal oxygen uptake ($v\dot{V}O_{2max}$) was 12.3 ± 0.7 km·h^{-1}. The maximal oxygen uptake ($\dot{V}O_{2max}$) on-field was 67.1 ± 5.3 mL·kg^{-1}·min^{-1}. The $\dot{V}O_2$ at the first and second ventilatory thresholds (VT1 and VT2) were identified at 67.0 ± 3.0% $\dot{V}O_{2max}$ (44.9 ± 3.3 mL·kg^{-1}·min^{-1}) and 84.7 ± 3.7% $\dot{V}O_{2max}$ (56.8 ± 3.8 mL·kg^{-1}·min^{-1}), respectively. Conclusions: This is a scarce on-field gas exchange assessment, conducted in an ecological context using a portable analyzer with highly trained national-level youth soccer players from the Argentine youth national team, which underlines their cardiorespiratory fitness, showcases their high-performance potential, offers valuable insights into a selective group of players, and provides a reference for larger-scale research on elite youth soccer and the long-term development of aerobic power and capacity.

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1. Introduction

Aerobic power (maximal oxygen uptake, or $\dot{V}O_{2max}$) and capacity (ventilatory thresholds) are among the most widely studied indicators of physical fitness in athletes, spanning various approaches and age groups [1–3]. From a sports perspective, $\dot{V}O_{2max}$ and vvo performance, and verify changes during a competitive season [4–8]. Typically, treadmill or cycle ergometers are used for aerobic power and capacity assessments, allowing for the dynamic analysis of cardiorespiratory responses [1]. In fact, such assessments deliver information of other relevant related information (e.g., velocity at maximal oxygen uptake—v$\dot{V}O_{2max}$, velocity at ventilatory thresholds, respiratory quotient, and training zones, among others) [1].

An increasing focus on essential physiological parameters is being observed among youth athletes [2,9]. Nevertheless, some studies proposing ecological approaches and protocols (on-field rather than laboratory protocols) involve quite heterogeneous populations, including school-aged youth, young athletes in training, and young athletes with professional prospects [10–13]. Despite advancements in portable gas analyzers, with some studies on school-aged children and young athletes in other sports, studies on high-level young athletes remain scarce in the ecological approach literature. Baquet et al. [10] analyzed the response to seven weeks of high-intensity endurance training in children aged 9 to 10 years. Ruiz et al. [12] compared values of $\dot{V}O_{2max}$ from schoolchildren when applying the 20-m Shuttle Run Test (20-m SRT). Ramírez et al. applied the 20-m SRT with gas analysis in adolescents to study the association between $\dot{V}O_{2max}$ and physical activity levels [11]. Bruzzese et al. [13] analyzed $\dot{V}O_2$ kinetics during a simulated competition in adolescent tennis players. All these studies have something in common, they employed on-field tests using portable or wearable equipment for gas exchange assessment, allowing researchers to explore $\dot{V}O_2$ response and related variables among different scenarios [10–13]. Therefore, better understanding a unique population, such as high-level young athletes, particularly in Argentine soccer where technological resources are limited, helps to better define the athletes' physiological profile.

Some contributions have already been reported with youth soccer players [5,6,8,14–16]. Chamari et al. [5] reported average $\dot{V}O_{2max}$ values of 4.3 ± 0.4 L·min^{-1} (61.1 ± 0.4 mL·kg^{-1}·min^{-1}) in Caucasian adolescent soccer players (17.5 ± 1.1 years old). Gomez-Piqueras et al. [6] measured $\dot{V}O_{2max}$ in soccer players under 15 years old, reporting average values of 56 mL·kg^{-1}·min^{-1}. Regarding younger age categories, scientific evidence in soccer is limited [14]. However, these studies have directly measured $\dot{V}O_{2max}$ by applying protocols on treadmills instead of on the field. While $\dot{V}O_{2max}$ values should not differ from those obtained in field tests, a significant disparity in the velocity at which $\dot{V}O_{2max}$ is reached (v$\dot{V}O_{2max}$) would be expected, with lower values observed in field tests [8,15]. The v$\dot{V}O_{2max}$ is typically used by coaches to segment training loads at these ages [8,16].

Argentina is the current and three-time Men's World Cup Champion, as well as the current and most successful team in Copa América history, but there are no on-field cardiorespiratory studies with gas exchange collection involving its youth players. The existing gas exchange study was conducted in a lab-based setting involving adults. [17]. While our study focuses on young athletes rather than adults (which we plan to explore in future research), understanding the profile of highly trained/elite youth soccer players in Argentina is key to better understanding the cardiorespiratory profile of emerging athletes.

On-field tests using portable or wearable equipment to assess gas exchange are essential for understanding the cardiorespiratory responses of soccer players. These tests provide important performance-related information that supports the development of both youth and professional athletes. Although by using global position systems (GPS) [18] and even inertial measurement units, we have obtained a lot of information about external load during training and competition, there is still a gap in the physiological domain (internal load), particularly regarding data collection in ecological settings.

As can be observed, studies on this topic (aerobic power and capacity assessment in soccer players) have been largely conducted in laboratory settings, particularly using treadmills. Although these studies have provided valuable insights into physiological aspects of performance in soccer, it is evident that they present inherent restrictions in replicating real-world scenarios. In fact, laboratory-based research struggles to account for critical physical, mental, and environmental factors that influence athletic performance in dynamic sports settings. Despite that, the use of portable and wireless equipment to conduct on-field assessments allows for a more ecologically valid analysis. This approach is particularly relevant for sports such as soccer, where repeated sprints and high-intensity intervals occur unpredictably, or for disciplines where treadmill-based studies fail to replicate real environmental conditions. By addressing these limitations, this study attempts to provides a realistic assessment with highly trained youth field soccer players. Thus, considering the scarcity of studies evaluating the on-field cardiorespiratory profile of national-level athletes, especially in Argentine soccer where technological resources are limited, the main objective of this study was to identify the on-field cardiorespiratory fitness profile of youth players from the Argentine Football Association (AFA). This would help to better define the physiological profile of these athletes. Our hypothesis was that these highly trained national-level youth soccer players will demonstrate excellent on-field cardiorespiratory fitness when assessed using the 20-m SRT with a portable metabolic analyzer in an ecological setting.

2. Materials and Methods

2.1. Participants

The study population consisted of ten (n = 10; central n = 4; left fullback n = 2; central midfielder n = 2; striker n = 2) highly trained youth field soccer players (13.6 $\pm$ 1.3 years old) from both the first league of the AFA and members of the national team in their age group category. Regarding inclusion criteria, participants must be federated AFA soccer players, actively competing, and have been continuously trained for at least two years. They should be highly trained youth field soccer players from the AFA's first league or members of the national team in their age group. This study was approved by the Ethics Committee while adhering to Resolution 1480/11 of the Ministry of Public Health of Argentina. All players received medical clearance from the club's physician, including a physical fitness certification, and parental approval was obtained.

2.2. Procedures

The experimental protocol took place in Buenos Aires, Argentina, in November 2022, during the break for the Qatar 2022 World Cup. The players were scheduled to arrive at 9:00 a.m. Measurements were taken on the training field with the players wearing their competition attire (Figure 1). Each volunteer completed one testing session under similar environmental conditions. Each session comprised anthropometric assessments, baseline measurements (5 min of passive rest), 5 min on-field warm-up at a moderate intensity followed by 5 min of passive recovery, and an on-field 20-m SRT while coupled with a wearable metabolic system for cardiorespiratory assessment.



Figure 1. Clothing, measurement location, and the wearable metabolic system.

2.3. Anthropometric Component

Body mass and standing height were measured according to the protocols established by the International Society for the Advancement of Kinanthropometry. The players were weighed without shoes using a portable electronic scale (MC-580; TANITA CORP of America, Issaquah, WA, USA) with a resolution of 0.1 kg. Height was measured with a stadiometer (SECA 206, São Paulo, Brazil). Body Mass Index (BMI; $kg \cdot m^{-2}$) was calculated. To provide a more detailed characterization of the sample, peak height velocity (PHV) was also estimated [19].

2.4. Cardiorespiratory Component and 20-m Shuttle Run Test (20-m SRT)

The cardiorespiratory exercise test was conducted on-field using the 20-m SRT [16,20]. This test involves running back and forth between two lines set 20 m apart, following the pace set by an audio signal. The test starts at a running velocity of 8.5 $km \cdot h^{-1}$ and increases by 0.5 $km \cdot h^{-1}$ each minute. The average temperature during the test ranged from 22 to 24 °C.

All participants used a portable gas-analyzer for cardiorespiratory assessment, the K5 wearable metabolic system® (COSMED K5, COSMED, Rome, Italy). Initially, preliminary warm-up and calibration routines (prior to each test) were applied according to the manufacturer's instructions. Pulmonary gas exchange was continuously measured using the dynamic micro-mixing chamber mode, at rest (2 min) and during the 20-m SRT. The mixing chamber option applied to K5, involves a dynamic micro-mixing chamber technology (IntelliMET™, Patent US 9581539) where proportional fractions of expired gas of some breaths are sampled inside a small chamber of ~2 mL (a conventional mixing chamber has 6–8 L); thus, a moving average of gas fractions is obtained to calculate mean $\dot{V}O_2$ and carbon dioxide production ($\dot{V}CO_2$) values.

First (VT1) and second ventilatory thresholds (VT2) [21], their respective running velocities (vVT1 and vVT2), as well as the respiratory exchange ratio (RER) expressed as the ratio of carbon dioxide (CO_2) produced to oxygen (O_2) consumed during metabolism, were calculated [21]. The test was terminated when participants either failed to reach the 20 m line twice consecutively in time with the beeps or chose to stop due to fatigue or discomfort. The $\dot{V}O_{2max}$ and respective velocity ($v\dot{V}O_{2max}$) was accepted when at least two of the following criteria were met: (a) flattening of $\dot{V}O_{2max}$ despite an increase in running velocity

($\Delta\dot{V}O_2$ < 150 mL O_2), (b) reaching an RER of 1.09 or higher, and (c) inability to continue running. Participants avoided vigorous exercise in the previous 24 h, were well-fed and hydrated, and abstained from caffeine, alcohol, or any stimulant drink the day prior to and on the test day. Similar meals 24 h before testing were recommended for all participants. The sample size was selected for convenience, focusing on highly trained youth Argentine field soccer players participating in the first league of the Argentine Football Association (AFA) in the youth categories, and members of the national team in their age group. A descriptive analysis was applied and reported for all variables.

3. Results

A total of ten (n = 10 males) highly trained youth field soccer players were measured on-field. The average maturational age was at the point of peak height velocity (PHV). However, the minimum and maximum values found indicate that there were children who were −2.17 years and +2.16 years from PHV, suggesting they were between Tanner stages 2 and 5.

Figure 2 (Panel A and B) displays the $\dot{V}O_2$ and $\dot{V}CO_2$ kinetics, along with the identification of the ventilatory thresholds VT1 and VT2 of a single participant. Figure 2 panel C shows mean values and standard deviations for $\dot{V}O_2$ at VT1, $\dot{V}O$ at VT2 and $\dot{V}O_{2max}$, and respective velocities during the 20-m SRT.

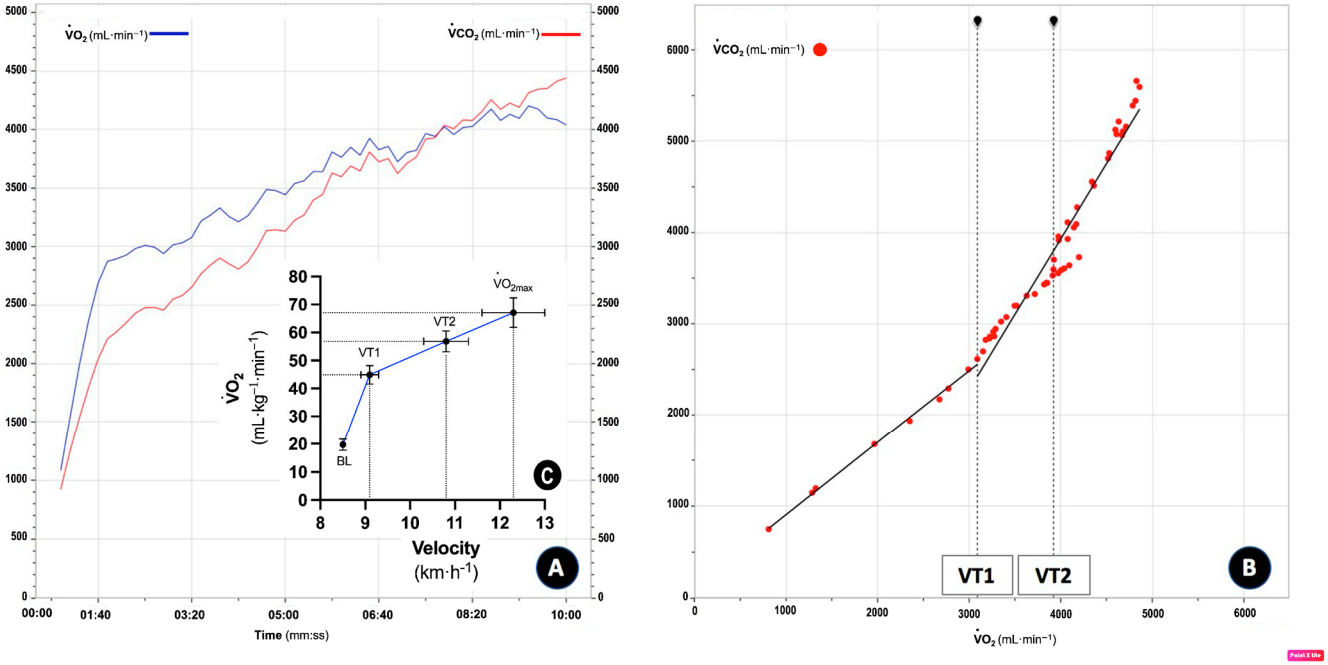


Figure 2. Plots from a representative participant showing $\dot{V}O_2$ (solid blue) and $\dot{V}CO_2$ (solid red) vs. time during a 20-m SRT (Panel (**A**)), and ventilatory thresholds VT1 and VT2 (Panel (**B**)); Panel (**C**) shows mean values and standard deviations for $\dot{V}O_2$ (solid blue) at VT1, $\dot{V}O$ at VT2 and $\dot{V}O_{2max}$, and respective velocities during the 20-m shuttle run test (20-m SRT; n = 10).

4. Discussion

The main aim of the current study was to identify the on-field cardiorespiratory fitness profile of highly trained youth field players from the AFA's first league and national team members in their age group (see Table 1 and Figure 2). Their cardiorespiratory profile seems to exceed those reported in other related studies and is comparable to that of adult soccer players from the Argentine first division. In our study, mean $\dot{V}O_{2max}$ during the 20-m SRT was 67.1 ± 5.3 mL·kg^{-1}·min^{-1}, like those found in professional adult soccer

players [4], which is consistent with several previously published studies. Chamari et al. [5] measured $\dot{V}O_{2max}$ in 34 youth soccer players from Tunisia and reported average values of 61.1 ± 4.6 mL·kg^{-1}·min^{-1}. The same research group measured $\dot{V}O_{2max}$ in ten youth soccer players from Norway [22] and reported average values of 65.4 ± 5.0 mL·kg^{-1}·min^{-1} and 70.7 ± 4.3 mL·kg^{-1}·min^{-1}. On the other hand, McMillan et al. [23] measured $\dot{V}O_{2max}$ in eleven youth soccer players from Scotland and reported average values of 63.4 ± 5.6 mL·kg^{-1}·min^{-1}. The comparison among the various studies highlights the cardiorespiratory quality of our sample.

Table 1. Anthropometrics and cardiorespiratory response to a 20-m shuttle run test (20-m SRT; *n* = 10) while using a wearable metabolic system. Mean ± SD values with respective 95% confidence intervals are displayed.

	Mean ± SD	**95% CI**
Age (years old)	13.6 ± 1.3	12.5 to 14.6
Body mass (kg)	56.7 ± 11.8	48.0 to 65.0
Height (cm)	163.9 ± 12.3	155.0 to 172.0
BMI (kg·m^2)	20.9 ± 2.2	19.3 to 22.4
PHV (years)	0.10 ± 1.40	−0.93 to 1.09
Shuttles (*n*)	74.2 ± 14.0	64.0 to 84.0
Total distance (m)	1484.0 ± 279.2	1284.0 to 1683.0
Stage achieved	8.5 ± 1.4	7.5 to 9.4
Maximal Velocity (km·h^{-1})	12.3 ± 0.7	11.7 to 12.7
$\dot{V}O_{2max}$ (mL·kg^{-1}·min^{-1})	67.10 ± 5.30	63.20 to 70.80
$\dot{V}O_{2max}$ (L·min^{-1})	3.82 ± 0.88	3.20 to 4.45
v$\dot{V}O_{2max}$ (km·h^{-1})	12.3 ± 0.7	11.7 to 12.7
$\dot{V}O_2$ at VT1 (mL·kg^{-1}·min^{-1})	44.90 ± 3.30	42.50 to 47.20
$\dot{V}O_2$ at VT2 (mL·kg^{-1}·min^{-1})	56.80 ± 3.80	54.00 to 59.0
$\dot{V}O_2$ at VT1 (%$\dot{V}O_{2max}$)	67.00 ± 3.00	64.80 to 69.10
$\dot{V}O_2$ at VT2 (%$\dot{V}O_{2max}$)	84.70 ± 3.70	82.00 to 87.00
vVT1 (km·h^{-1})	9.1 ± 0.2	8.9 to 9.1
vVT2 (km·h^{-1})	10.8 ± 0.5	10.3 to 11.1
RER	1.10 ± 0.10	1.02 to 1.10
$\dot{V}E$ at $\dot{V}O_{2max}$ (L·min^{-1})	118.5 ± 28.2	98.0 to 138.0

Legend: BMI: body mass index; PHV: peak height velocity; $\dot{V}O_2$: oxygen uptake; $\dot{V}O_{2max}$: maximal oxygen uptake; v$\dot{V}O_{2max}$: velocity at $\dot{V}O_{2max}$; VT1: first ventilatory threshold; VT2: second ventilatory threshold. vVT1: velocity at first ventilatory threshold; vVT2: velocity at second ventilatory threshold RER: respiratory exchange ratio. $\dot{V}E$: minute ventilation; 20-m SRT: 20-m shuttle run test; SD: standard deviation; CI: confidence interval.

Other studies have reported lower values than those found in the present work for youth soccer players. Sperlich et al. [24] measured $\dot{V}O_{2max}$ in nine 14 year-old German soccer players and reported average values of 55.1 ± 4.9 mL·kg^{-1}·min^{-1}. Sporis et al. [25] measured 48 under 19 year-old Croatian soccer players and reported values from 57 to 62 mL·kg^{-1}·min^{-1}. Gómez-Piqueras et al. [6] evaluated three categories of Spanish soccer players aged 15 to 18 years (*n* = 79) and reported average values of 56 to 58 mL·kg^{-1}·min^{-1}. Vänttinen et al. [26] measured three youth categories (11, *n* = 13; 13, *n* = 14; and 15 years old, *n* = 12) in Finnish soccer and reported average values of 52.3 ± 3.1, 53.1 ± 3.0, and 55.0 ± 3.9 mL·kg^{-1}·min^{-1} for 11, 13, and 15 years old, respectively. Wong et al. [27] measured 46 Chinese soccer players (~13 years old) and reported average values of 54.9 ± 0.9 mL·kg^{-1}·min^{-1}. The only Argentine study [14] reported average values of 47.1, 49.8, and 53.0 mL·kg^{-1}·min^{-1} for 8–10 (*n* = 20), 11–13 (*n* = 20), and 14–16 years old (*n* = 20), respectively. In fact, the values from our current study are similar or higher than those reported in other leagues. However, none of the cited studies measured $\dot{V}O_{2max}$ in an ecological condition, i.e., on-field. Another contribution of this current on-field approach

was the analysis of ventilatory thresholds (VT1 and VT2) in this population (highly trained youth field soccer players), which were assessed on-field, which is scarce in the literature.

The direct assessment of cardiorespiratory capacity in soccer has typically been conducted in laboratory settings, which greatly reduces the ecological validity of the studies. Thus, our study, conducted under real-world conditions, helps fill this gap. One key reason for conducting evaluations in the field is that subjects react differently in a field environment compared to on a treadmill. While $\dot{V}O_{2max}$ remains consistent between treadmill and field conditions in adults [15], the $v\dot{V}O_{2max}$ shows differences when comparing the two settings [8]. Billat and Koralsztein (1996) [28] defined $v\dot{V}O_{2max}$ as the minimum velocity at which maximum oxygen consumption ($\dot{V}O_{2max}$) is achieved. Although both variables are measured simultaneously, $v\dot{V}O_{2max}$ can be influenced by the testing protocol, whereas $\dot{V}O_{2max}$ remains consistent. Riboli et al. (2016) [29] compared three protocols in the same individual and observed different $v\dot{V}O_{2max}$ values but similar $\dot{V}O_{2max}$ values (continuous treadmill test: $\dot{V}O_{2max}$ 56.7 $mL \cdot kg^{-1} \cdot min^{-1}$ vs. $v\dot{V}O_{2max}$ 16.8 $km \cdot h^{-1}$; Incremental test with increments of 1 $km \cdot h^{-1}$ every 2 min: $\dot{V}O_{2max}$ 56.6 $mL \cdot kg^{-1} \cdot min^{-1}$ vs. $v\dot{V}O_{2max}$ 18.6 $km \cdot h^{-1}$; Incremental test with increments of 1 $km \cdot h^{-1}$ every 1 min: $\dot{V}O_{2max}$ 57.3 $mL \cdot kg^{-1} \cdot min^{-1}$ vs. $v\dot{V}O_{2max}$ 20.7 $km \cdot h^{-1}$. It is clear that $v\dot{V}O_{2max}$ is protocol dependent. The same occurs when comparing $v\dot{V}O_{2max}$ on a treadmill and in the field. Running velocity is influenced by the environment (treadmill or field), whereas $\dot{V}O_{2max}$ remains constant. Cappa et al. (2014) [7] compared $v\dot{V}O_{2max}$ in the field and $v\dot{V}O_{2max}$ on a treadmill using the same protocol (UNCA test, with increments of 1 $km \cdot h^{-1}$ every 1 min (treadmill: $v\dot{V}O_{2max}$ 15.6 $km \cdot h^{-1}$ vs. field: $v\dot{V}O_{2max}$ 13.6 $km \cdot h^{-1}$. In a second study, the same protocol was replicated with professional soccer players [8] (treadmill: $v\dot{V}O_{2max}$ 15.6 $km \cdot h^{-1}$, $\dot{V}O_{2max}$ 46.6 $mL \cdot kg^{-1} \cdot min^{-1}$ vs. Field: $v\dot{V}O_{2max}$ 13.6 $km \cdot h^{-1}$, $\dot{V}O_{2max}$ 48.1 $mL \cdot kg^{-1} \cdot min^{-1}$). Both studies showed that while $\dot{V}O_{2max}$ was similar between treadmill and field tests, $v\dot{V}O_{2max}$ differed significantly. Thus, although the comparison between treadmill and field, focusing on $v\dot{V}O_{2max}$, has not been conducted in children, studies on $\dot{V}O_{2max}$ do exist. Ruiz et al. (2008) [12], using the 20-m SRT, demonstrated no differences in $\dot{V}O_{2max}$ in children. However, focusing on running velocity as a variable is relevant because coaches use laboratory-based or field-based $v\dot{V}O_{2max}$ to prescribe training loads. Additionally, ventilatory thresholds and respective velocities may differ between the two environments [7,8]. However, although young athletes train and compete on the field, making it important to assess physiological responses in that environment, most sports centers in Argentina lack access to portable analyzers.

Thus, the most cost-effective way to study cardiorespiratory behavior in youth athletes is by measuring the final velocity achieved in an indirect field test. The most used test, due to its validity, reliability, safety, and sensitivity, is the 20-m SRT [16]. This is the only aerobic test with international standards for global comparisons [27]. In Argentina, there is scientific evidence obtained from using the 20-m SRT indirectly in school populations [30,31]. However, until the present study, no direct $\dot{V}O_{2max}$ measurements during the 20-m SRT had been conducted in our country. The aerobic performance level of the Argentine highly trained field soccer players in this study was above the 80th percentile when compared with international standards [32] or national data [30,31]. It is important to note that the reference tables were created in a school setting. Therefore, it would be valuable in the future to establish aerobic performance norms for highly trained youth field soccer players in the AFA (Argentine Football Association).

The high $\dot{V}O_{2max}$ values found may be due to several factors. Typically, in AFA clubs, players are selected at early ages through a series of ball-focused tests, choosing those who perform best during gameplay. Subsequently, they are exposed to three weekly sessions of high-intensity exercise. It is well reported that high-intensity training produces significant

improvements in $\dot{V}O_{2max}$ [4,10]. Weekend matches also present a significant workload (external and internal). It is important to be aware that the same field dimensions of adults are used at these categories, i.e., considering that the playing field is the same as that for adults, and the stride length is shorter the younger the age, they end up taking a greater number of steps. There is a higher exertion level. Castagna et al. monitored soccer players with an average age of 11 years during competitive matches and found they covered an average of 6175 m per match [33]. Algroy et al. (2021) monitored 14-year-old soccer players in 23 official Norwegian league matches and found they covered an average of 7645 m [34]. Bucheitt et al. (2010) measured players from six youth categories and found they covered between 6549 m (13 years) and 8707 m (18 years) [35]. The high $\dot{V}O_{2max}$ values obtained can be explained by (i) their top-level physical fitness and technical skills as national team athletes, and (ii) the intense weekly training stimuli and competitive demands within these age categories of Argentine soccer.

We acknowledge potential limitations regarding the sample size of 10 athletes (highly trained youth field soccer players from both the first league of the AFA and members of the national team in their age group category) out of a total population of approximately 23 to 26. It is pertinent here to underline the rationale behind this choice, specifically given that this is a brief report. The total population consists of only 23 to 26 athletes, all of whom have been recently selected for national teams. Given this small overall population, our sample of 10 represents a substantial proportion (~38% to 43%) of all eligible athletes. While a larger sample would always be desirable, the practical constraints of working with a highly selective group made broader recruitment difficult. Also, highly trained athletes have demanding schedules, making access for research particularly challenging. Factors such as competition calendars, training commitments, and limited availability restricted our ability to assess all athletes within the population. Despite these constraints, we made efforts to ensure the sample was as representative as possible. Likewise, since this is a brief report, the objective is to describe key trends and observations, not to conduct inferential statistical analysis. Small sample sizes are common in brief reports/case studies/case reports, which focus on concise yet meaningful insights rather than broad generalizations. Unlike studies with more dissimilar populations, our target group is highly homogeneous, as all participants share similar training backgrounds, performance levels, and recent national team selection. This reduced variability helps ensure that meaningful insights can still be drawn from a smaller sample. As mentioned above, many studies in highly trained/elite/world-class sports science have worked with similarly small samples due to the difficulty of accessing these populations. Studies on high-performance athletes habitually rely on descriptive analyses and often use few statistical approaches, and with sample sizes constrained by real-world limitations. While this brief report offers a valuable picture of this exclusive cluster, future studies could build upon these findings with larger samples as more athletes and technology become available. Thus, given the small overall population (23 to 26 athletes), the substantial proportion included in the study (~38% to 43%), the logistical and technological challenges, and the exploratory nature of a brief report, we believe the sample size of 10 is justified and still offers meaningful insights. Finally, we acknowledge the limitation that our sample includes players from different positions, which may influence metabolic demands. However, due to the inherent difficulty in accessing elite-level athletes, it was not feasible to obtain a homogeneous sample from a single position. Despite this limitation, all included players compete at a high level, and their aerobic power and capacity, and related variables are representative of the modern game for highly trained youth field soccer players who are members of the national team in their age group category. Future studies with larger, position-specific samples could provide further insights into the metabolic differences across playing roles.

5. Conclusions

This is a rare on-field gas exchange assessment conducted in an ecological context using a portable analyzer with highly trained national-level youth soccer players from the Argentine youth national team which underlines their cardiorespiratory fitness and showcases their high-performance potential. The importance of this study lies in the valuable data on a highly selective group of soccer players who are actively competing. Direct $\dot{V}O_2$ assessments in an ecological context on highly trained youth soccer players remain limited, especially in this age group and competitive level. This brief report offers valuable insights into a selective group of players and provides a reference for larger-scale research on elite youth soccer and the long-term athletic development of aerobic power and capacity.

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Abbreviations

The following abbreviations are used in this manuscript:

AFA	Argentine football association
20-m SRT	20-m shuttle run test
BMI	Body mass index
CO_2	Carbon dioxide
$\dot{V}CO_2$	Carbon dioxide production
VT1	First ventilatory threshold
GPS	Global position system
$\dot{V}O_{2max}$	Maximal oxygen uptake
$\dot{V}E$	Minute ventilation
O_2	Oxygen
$\dot{V}O_2$	Oxygen uptake
PHV	Peak height velocity
RER	Respiratory exchange ratio

VT2	Second ventilatory threshold
vVT1	Velocity at first ventilatory threshold
$v\dot{V}O_{2max}$	Velocity at maximal oxygen uptake
vVT2	Velocity at second ventilatory threshold

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