



Aerobic power profile in young athletes according to age and bio banding

Perfil de potencia aeróbica en atletas jóvenes según la edad y la banda

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Abstract

Introduction and Objective. VO_2 max values can be obtained either through direct measurement using laboratory tests or estimated indirectly via field tests. However, evaluative cut-off points are also necessary, which must be adjusted to the individual characteristics of the subjects, including the sport discipline practiced. The aim of this study was to design a profile to evaluate aerobic power in young athletes of both sexes, according to chronological age ranges and biological maturation bio-bands.

Methodology. A quantitative, cross-sectional, descriptive study was conducted with a sample of 613 athletes aged 11 to 20 years. Maximum oxygen consumption (VO_2 max) was estimated through the 20 m shuttle run test, while anthropometric variables were assessed using the ISAK protocol. Somatic maturation bio-bands were determined using peak height velocity. To construct the aerobic power profile, cut-off points were established using the mean and standard deviation, with data processed in SPSS 28.0.

Results. Findings showed that male athletes presented higher VO_2 max values than females. Across all age groups and maturity levels, athletics participants of both sexes demonstrated the highest VO_2 max values, with an average of $60 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ for males and $51 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ for females. An exception was observed in boys aged 11 to 12.9 years practicing wrestling and Greco-Roman wrestling, who showed lower values of $57.4 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$.

Discussion. The results highlight the influence of sex, sport discipline, and maturation stage on aerobic power. Athletics athletes consistently outperform other groups, underscoring the sport-specific demands and training effects. The findings also suggest that establishing bio-band-based cut-off points allows for a more individualized and accurate evaluation of aerobic capacity in youth athletes.

Conclusions. The constructed cut-off points serve as a valuable reference for evaluating aerobic power and qualifying aerobic physical fitness levels in young athletes. These references take into account both the sport practiced and individual characteristics, providing coaches and sports scientists with a more tailored tool for athlete monitoring and development.

Keywords

Maximum oxygen consumption; PHV; somatic maturation; sports; VO_2

Resumen

Introducción y Objetivo. Los valores de VO_2 máx pueden obtenerse mediante mediciones directas con pruebas de laboratorio o pueden estimarse indirectamente mediante pruebas de campo. También se requieren puntos de corte evaluativos, que se ajustan a las características individuales de los sujetos, incluida la disciplina deportiva que practican. El objetivo de esta investigación es diseñar un perfil para evaluar la potencia aeróbica en jóvenes atletas de ambos sexos según rangos de edades cronológicas y bio-bandas de maduración biológica.

Metodología. Se ejecutó un estudio cuantitativo, de corte transversal y de alcance descriptivo. Se evaluaron 613 deportistas con edades entre 11 y 20 años. El consumo máximo de oxígeno se estimó a través del 20 m shuttle run test, y las variables antropométricas mediante el protocolo de la ISAK. Para establecer las bio-bandas de maduración somática se empleó el Pico de Crecimiento en talla. Para la determinación del perfil de potencia aeróbica se realizaron puntos de corte con la media y la desviación estándar, procesados mediante el SPSS 28.0.

Resultados. Se observa que el grupo masculino presenta mayores valores que el femenino. Por su parte, los sujetos de atletismo de ambos sexos presentan valores superiores de VO_2 máx en todos los grupos de edad y por grado de maduración, con un promedio de $60 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ para hombres y $51 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ para mujeres, con la excepción de los varones de lucha libre y grecorromana de 11 a 12,9 años, quienes registraron $57,4 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$.

Discusión. Los hallazgos evidencian la influencia del sexo, la disciplina deportiva y la etapa de maduración en la potencia aeróbica. Los atletas de atletismo destacan consistentemente con los valores más altos, lo que refleja tanto las demandas específicas de la disciplina como los efectos del entrenamiento. Asimismo, el uso de bio-bandas permite establecer referencias más individualizadas y precisas para la evaluación de la capacidad aeróbica en poblaciones jóvenes.

Conclusiones:

Los puntos de corte establecidos constituyen una referencia útil para evaluar la potencia aeróbica y calificar el nivel de aptitud física aeróbica de los atletas. Dichas referencias consideran tanto el deporte practicado como las características individuales de los sujetos, ofreciendo a entrenadores y científicos del deporte una herramienta más ajustada para el seguimiento y desarrollo de los deportistas.

Palabras clave

Consumo máximo de oxígeno; Deportes; maduración somática; PHV; VO_2 máx.



Introduction

Muscle energy is provided by three mechanisms that act simultaneously, with differences in their power and capacity respectively (Subiela, 2019), among them we have the aerobic power that has been defined as the maximum capacity of oxygen consumption ($\text{VO}_2 \text{ max}$) of a subject (García et al., 2025; Subiela, 2005) and is directly related to the maximum energy production in the unit of time, at the expense of aerobic metabolism. therefore, $\text{VO}_2 \text{ max}$ represents the equivalent for the metabolic manifestation of the concept of aerobic power and its values are expressed in absolute terms (L/min or ml/min) and in relative form ($\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) (Katch et al., 2015, p. 237), highlighting that this relative form of expressing $\text{VO}_2 \text{ max}$ per kg provides information on body composition and cardiovascular fitness (Padilla-Alvarado et al., 2018).

$\text{VO}_2 \text{ max}$ values can be obtained through direct measurement using laboratory tests that require the use of gas analyzers either with mixing chamber technology or Breath-by-Breath systems depending on the objective (García-Tabar et al., 2018; Ward, 2018), also using costly ergometers such as cycloergometers or treadmill, which guarantee greater control in the mechanical variables, can limit the maximum performance in consideration of the performer's sport specialty. Therefore, laboratory tests present advantages and disadvantages depending on the ergometer used. The protocols are usually designed to last approximately between 6-8 and 14-16 minutes.

On the other hand, $\text{VO}_2 \text{ max}$ can also be estimated indirectly by applying field tests, with the known advantages of simplicity in their application and approximation to the reality of the sport being practiced. Thus, the accurate measurement of cardiorespiratory fitness is considered essential to determine the levels of functional fitness and to monitor the effects of possible intervention. However, the measurement or prediction of $\text{VO}_2 \text{ max}$ is one of the most important tests of cardiorespiratory fitness.

However, it is not enough just to estimate or measure $\text{VO}_2 \text{ max}$, as evaluative categories are also required, which are adjusted to the individual characteristics of the subjects, including the sport discipline practiced, since cardiovascular fitness is considered as an important indicator for athletic performance in many sports, with known gender differences (Handelsman et al., 2018; Hunter et al., 2023; Hunter & Senefeld, 2024), given that many sports in their assessment of the bioadaptation profile, require the combination of functional and morphological variables that provide information related to the sex and age in which the athlete is, thus allowing the use of standards at a certain point in the athlete's preparation; Aerobic power has normative standards for age, gender, training level, and body size. (McArdle et al., 2015, p. 236), but it is not common for maturity status or degree of maturation in athletes.

In this sense, another fundamental aspect is maturation, which can be assessed in different ways and is a determining factor in differentiating the maturational state with respect to chronological age; assessment methods known as biological maturation have been developed, in which radiographs must be taken and the subject's bone age is established by means of different techniques (Bayley & Pinneau, 1952; Garn & Tanner, 2006; Malina et al., 2018); there is also the estimation of somatic maturation based on anthropometric measurements (Fransen et al., 2018; Mirwald et al., 2002; Pérez et al., 2015) and the moment of adolescent growth spurt (Towlson & Cumming, 2022). Based on this characterization, biobands can be generated, which can consider the degree of maturation for an age range, whether a 12-year-old subject is an early, normal or late maturer (Cumming et al., 2017a); or the degree of maturation where subjects of different ages are grouped according to their peak growth velocity (PHV), being pre-PHV, during PHV or after PHV (Padilla-Alvarado, 2021; Padilla-Alvarado & Lozada-Medina, 2012; Towlson et al., 2021).

In this order of ideas, its application in training load management and the association with aerobic performance in young athletes has been demonstrated. (Beyer et al., 2020), To mitigate the impact of maturation on performance the degree of maturation should be monitored (Cumming et al., 2017b; de Macedo et al., 2025), since decreases or increases in performance may occur according to the degree of maturation, therefore, the intervention plan should be adjusted considering this aspect. Therefore, using $\text{VO}_2 \text{ max}$ assessment strategies according to bio banding, considering interindividual differences in the state of maturity among young people of the same chronological age (Malina et al., 2019), this could be advantageous for the development of the athletes regardless of their degree of maturity (Chimera et al.,

2024) and the evaluation of physical fitness will be more objectively assessed, considering that the references currently used for VO_2 qualification in young athletes are presented by chronological age only, without discriminating the degree of maturation for each sport.

In consideration of the recommended need for physical fitness monitoring to inform decision making, the application of international fitness tests using valid, reliable and standardized measures is implemented (Lang et al., 2023), in this sense the 20 m shuttle run test, represents a suitable instrument to characterize aerobic power and compare between populations. This test is one of the most used in practice by coaches and researchers when it comes to estimating VO_2 max in healthy youth populations, considered a broad health indicator for population health surveillance in children and youth (Lang, 2018), A review found that South American countries have worse physical performance, associated with income inequality (Lang et al., 2018), however in that same work they indicate that African countries present better performances, although there are regulations that consider children and adolescents in South America. (Aubert et al., 2022; Tomkinson et al., 2017), it should be taken into account that it is very likely that the athletic levels of the population evaluated in South America were low, since they were not a sports population, and furthermore, the sample of South American countries did not include studies conducted in young Venezuelans, limiting in some way the use of the aforementioned standard to characterize mainly the sports population.

Therefore, it is necessary to draw cut-off points for the evaluation of aerobic power in young athletes, considering the sports specialty practiced, age, sex and the level of maturation acquired up to the moment of the evaluation. Consequently, the aim of the present work is design a profile to evaluate aerobic power in young athletes of both sexes according to chronological age ranges and bio- bands maturation biological.

Method

Design and participants

The study is approached from the quantitative, in a non-experimental design, with a descriptive scope, cross-sectional and in the field context. The sample consists of 613 young athletes selected from the state of Barinas-Venezuela, in the specialties of: Athletics, Swimming, Speed Skating, Weightlifting, Taekwon do, Table Tennis, Water Polo, Basketball, Volleyball, Baseball, Boxing, Fencing, Field Soccer, Judo and Wrestling and Greco-Roman Wrestling; selected according to the functional controls that these sports carry out in their preparation processes. The ages were between 11 and 20 years old chronologically for both sexes, with a training frequency between three (3) to five (5) days a week, and an average of 150 minutes per work session, a total of 226 female athletes and 387 male athletes.

All were previously informed, and their participation was authorized by their representatives in the case of minors. The study was approved (Approval number: 0043/2023) by the Ethics Committee of the Observatory of Research in Physical Activity and Sports Sciences (OICAFD) of the National Experimental University of the Western Plains Ezequiel Zamora (UNELLEZ) and international standards established in the Helsinki Declaration for the development of research on human beings. Inclusion criteria were to be healthy at the time of the evaluation and with a minimum training continuity of 12 weeks without injuries or diseases, and with a minimum age of 11 years old up to 20 years old.

Procedures

Protocols for the estimation of aerobic power (VO_2 max) and somatic maturation bio-bands

The 20 m shuttle run test (Leger et al., 1988; Leger & Lambert, 1982) was used, and the equation recommend estimating aerobic power from 20mSRT performance (stage), sex, age, weight, and height in adolescents (Léger et al., 1984, p. 240); with a previous practice of familiarization by the subjects to be evaluated. The data were collected in a period of five (5) years, conducted during the evaluation and control processes programmed by the coaches of each of the sports. The protocol of the International Society for the Advancement of Kinanthropometry was used for the measurement of anthropometric

variables (Esparza-Ríos et al., 2019) of body mass, height, sitting height and skinfolds. All anthropometric measurements were performed by the authors-researchers, level II anthropometrists issued by the ISAK. The margin of error of the measurements was within the accepted limits (<5%).

Somatic maturation Bio-Bands were estimated with predictive equations for the evaluation of somatic maturation adjusted to the Venezuelan population (Pérez et al., 2015). Once the Peak Height Velocity (PHV) was calculated, to simplify the interpretation three (3) groups (J. Padilla-Alvarado, 2021; J. Padilla-Alvarado & Lozada-Medina, 2012) were generated according to the degree of maturity estimated in the PHV: before PHV (< - 0.5 years), during PHV ($\geq - 0.5 \leq + 0.5$ years) and after PHV (> + 0.5 years), so that those subjects who were within -0.5 years of reaching PHV were placed in the group before PHV and those who were 5 years after PHV were placed in the group after PHV, taking into account that the PHV transition is approximately 1 year (McLaren-Towlson, 2016).

Statistical model

The data were processed with the Statistical Package for the Social Sciences (SPSS-Statistical Package for the Social Sciences) version 28.0 for Windows ©, and figures using the R package v4.4. First, the Kolmogorov-Smirnov parametric statistical test was used to determine the normal distribution of the data, as recommended for studies in physical activity and sports science (Lozada-Medina et al., 2022). Once the distribution was corroborated (KS .89 p.400), the descriptive statistics of mean and standard deviation were calculated for the tests used and according to the grouping of the subjects in age (11 to 12.9 years, 13 to 14.9 years and 15-20 years) and in maturation bio-bands (before, during and after the PHV). The determination of the profile for aerobic power of performed the following cut-off points: below average (mean minus 1 standard deviation), average (mean $\pm$ 1 standard deviation) and above average (mean plus 1 standard deviation).

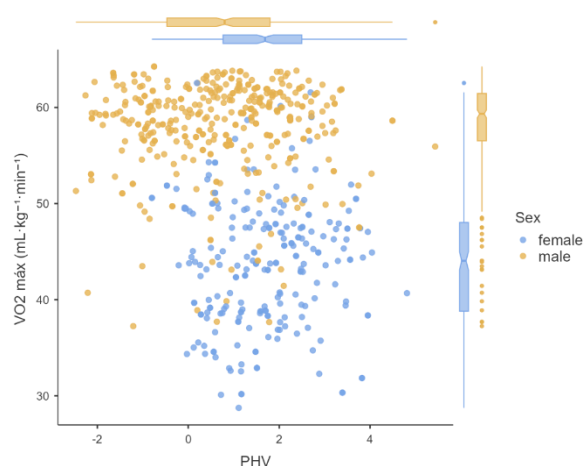
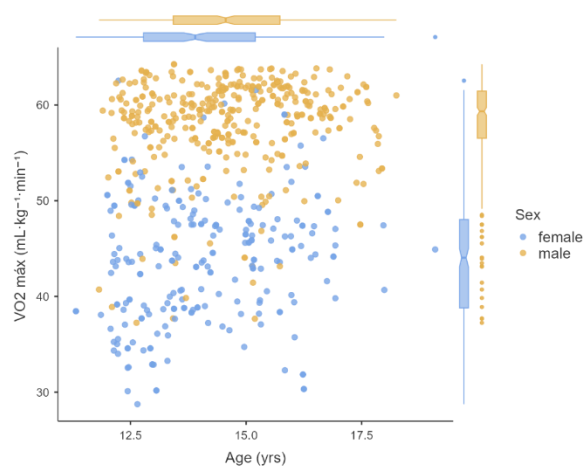
Results

Table 1 shows that female athletes have lower values for body weight, height and VO2 max, but higher mean values for fat percentage compared to male athletes. When comparing VO2 max means by sex using student's test, $p < 0,001$; mean difference= -14,24; the comparisons also shows differences, as illustrate in Figure 1 and 2, where the data cloud indicates that male athletes have higher VO2 max than in female athletes, when comparing either by age or by PHV.

Table 1. Descriptive statistics of the study group by sex

Variables	Sex	N	mean	SD
Body Weight (Kg)	female	226	50.98	11.51
	male	387	53.41	11.82
Height (Cm)	female	226	159.51	6.76
	male	387	165.89	10.27
% Body Fat	female	226	17.97	5.21
	male	387	9.95	3.54
VO ₂ máx (ML·Kg ⁻¹ ·Min ⁻¹)	female	226	43.81	6.59
	male	387	58.05	4.89

Note: N=number of cases; SD = standard deviation.

Figure 1. Data cloud and box plots for VO₂ max and PHV by sexFigure 2. Data cloud and box plots for VO₂ max and Age by sex

Aerobic power assessment profiles by age ranges

Tables 2 and 3 present the evaluative profiles for aerobic power in the Course Navette test, considering the specific sport and sex, as well as the age ranges. It can be seen how male athletes show higher performance, expressed in relative VO₂ max (mL·kg⁻¹·min⁻¹), in all age ranges, and with the same tendency in all sports, with the highest values reached by subjects between 15 and 20 years of age who practice athletics with 62.5 mL·kg⁻¹·min⁻¹ for men and 51.5 mL·kg⁻¹·min⁻¹ for women; on the other hand, the group of male subjects of wrestling and Greco-Roman wrestling from 11 to 12.9 years old presents the highest for that age group with the value of 57.4 mL·kg⁻¹·min⁻¹ and in women, the athletes show 49.2 mL·kg⁻¹·min⁻¹.

Table 2. Evaluation profile for aerobic power in male athlete's group in the 20 m shuttle run test (VO₂ max: mL·kg⁻¹·min⁻¹) by age

Sports	[11-12.9] years			[13 - 14.9] years			[15-20] years		
	below	Average	Above	below	Average	Above	below	Average	Above
Athletics	≤46.39	≥46.40 ≤53.80	≥53.81	≤49.99	≥49.00 ≤57.00	≥57.01	≤54.34	≥54.35 ≤62.52	≥62.53
Baseball	≤45.71	≥45.72 ≤52.82	≥52.83	≤48.20	≥48.21 ≤54.58	≥54.59	≤49.22	≥49.23 ≤57.38	≥57.39
Basketball	≤43.93	≥43.94 ≤50.74	≥50.75	≤46.72	≥46.73 ≤52.48	≥52.49	≤48.49	≥48.50 ≤57.25	≥57.26
Boxing	≤48.81	≥48.82 ≤52.31	≥52.32	≤47.51	≥47.52 ≤56.55	≥56.56	≤48.09	≥48.10 ≤59.00	≥59.01
Fencing	≤45.70	≥45.71	≥51.16	≤46.88	≥46.89	≥56.65	≤48.78	≥48.79	≥58.30

		≤51.15			≤56.64			≤58.29	
Judo	≤45.88	≥45.89 ≤54.89	≥54.90	≤48.96	≥48.97 ≤52.14	≥52.15	≤50.80	≥50.81 ≤55.63	≥55.64
Soccer	≤50.55	≥50.56 ≤55.89	≥55.90	≤51.65	≥51.66 ≤57.95	≥57.96	≤51.62	≥51.63 ≤60.97	≥60.98
Speed skating	≤49.01	≥49.02 ≤52.52	≥52.53	≤51.88	≥51.89 ≤55.39	≥55.40	≤55.82	≥55.83 ≤59.33	≥59.34
Swimming	≤46.22	≥46.23 ≤55.73	≥55.74	≤47.22	≥47.23 ≤56.73	≥56.74	≤49.77	≥49.78 ≤60.62	≥60.63
Table Tennis	≤49.09	≥49.10 ≤54.13	≥54.14	≤51.65	≥51.66 ≤57.18	≥57.19	≤54.69	≥54.70 ≤58.54	≥58.55
Tae kwon do	≤51.68	≥51.69 ≤56.99	≥56.00	53.23≤	≥53.24 ≤58.24	≥58.25	≤54.80	≥54.81 ≤61.07	≥61.08
Volleyball	≤45.37	≥45.38 ≤52.63	≥52.64	≤46.42	≥46.43 ≤54.29	≥54.30	≤48.46	≥48.47 ≤57.51	≥57.52
Water polo	≤43.94	≥43.95 ≤49.70	≥49.71	≤49.95	≥49.96 ≤52.87	≥52.88	≤45.80	≥45.81 ≤59.56	≥59.57
Weightlifting	≤39.51	≥39.52 ≤49.32	≥49.33	≤46.12	≥46.13 ≤56.64	≥56.61	≤48.83	≥48.84 ≤56.42	≥56.43
Wrestling and Greco-Roman	≤51.23	≥51.24 ≤57.43	≥57.44	≤48.95	≥48.96 ≤58.84	≥58.85	≤52.18	≥52.19 ≤58.75	≥58.76

Table 3. Evaluation profile for aerobic power in female athlete's group in the 20 m shuttle run test (VO_2 max: $mL \cdot kg^{-1} \cdot min^{-1}$) by age

Sports	[11-12.9] years			[13 - 14.9] years			[15-20] years		
	below	Average	Above	below	Average	Above	below	Average	Above
Athletics	≤47.72	≥47.73 ≤49.18	≥49.19	≤44.51	≥44.52 ≤52.72	≥52.73	≤44.96	≥44.97 ≤51.49	≥51.50
Basketball	≤38.67	≥38.68 ≤41.11	≥41.12	≤43.62	≥43.63 ≤50.53	≥50.54	≤46.58	≥46.59 ≤51.84	≥51.85
Fencing	≤41.79	≥41.80 ≤45.10	≥45.11	≤40.37	≥40.38 ≤48.10	≥48.11	≤42.75	≥42.76 ≤47.62	≥47.63
Judo	≤35.29	≥35.30 ≤41.14	≥41.15	≤40.37	≥40.38 ≤46.75	≥46.76	≤42.35	≥42.36 ≤49.51	≥49.52
Soccer	≤43.99	≥44.00 ≤45.68	≥45.69	≤44.37	≥44.38 ≤47.53	≥47.54	≤46.05	≥46.06 ≤47.51	≥47.52
Speed skating	≤36.87	≥36.88 ≤47.26	≥47.27	≤43.22	≥43.23 ≤46.23	≥46.24	≤44.88	≥44.89 ≤49.39	≥49.40
Swimming	≤38.25	≥38.26 ≤44.56	≥44.57	≤38.24	≥38.25 ≤47.25	≥47.26	≤43.57	≥43.58 ≤51.05	≥51.06
Table Tennis	≤39.89	≥39.90 ≤43.05	≥43.06	≤37.41	≥37.42 ≤46.11	≥46.12	≤40.30	≥40.31 ≤48.45	≥48.46
Tae kwon do	≤33.45	≥33.46 ≤48.73	≥48.74	≤42.66	≥42.67 ≤47.18	≥47.19	≤46.67	≥46.68 ≤47.75	≥47.76
Volleyball	≤33.20	≥33.21 ≤38.73	≥38.74	≤34.13	≥34.14 ≤40.81	≥40.82	≤37.32	≥37.33 ≤48.73	≥48.74
Water polo	≤32.49	≥32.50 ≤39.25	≥39.26	≤35.40	≥35.41 ≤39.29	≥39.30	≤36.64	≥36.65 ≤42.35	≥42.36
Weightlifting	≤33.56	≥33.57 ≤37.58	≥37.59	≤38.04	≥38.05 ≤40.67	≥40.68	≤38.46	≥38.47 ≤42.09	≥42.10
Wrestling and Greco-Roman	≤37.98	≥37.99 ≤46.37	≥46.38	≤41.63	≥41.64 ≤46.74	≥46.76	≤46.38	≥46.39 ≤48.58	≥48.59

When the results are presented according to the state of somatic maturation (Table 4 and 5), it is observed that the male group of athletics presents values over $60 mL \cdot kg^{-1} \cdot min^{-1}$ in the 3 categories; on the other hand, in the female group it is observed that with 47, 51 and $54 mL \cdot kg^{-1} \cdot min^{-1}$, the groups before during and after the PHV for athletics present the best performance.

Table 4. Evaluation profile for aerobic power in male athlete's group in the 20 m shuttle run test test (VO_2 max: $mL \cdot kg^{-1} \cdot min^{-1}$) by biobanding

Sports	Before the PHV			During the PHV			After the PHV		
	low	Average	high	low	Average	high	low	Average	high
Athletics	≤53.38	≥53.39 ≤60.14	≥60.15	≤57.07	≥57.08 ≤60.74	≥60.75	≤60.28	≥60.29 ≤66.23	≥66.24
Baseball	≤53.92	≥53.93 ≤57.20	≥57.21	≤53.12	≥53.13 ≤59.11	≥59.12	≤56.71	≥56.72 ≤63.17	≥63.18
Basketball	≤49.16	≥49.17 ≤54.42	≥54.43	≤50.97	≥50.98 ≤55.18	≥55.19	≤53.58	≥53.59 ≤58.54	≥58.55
Boxing	≤53.59	≥53.60 ≤55.70	≥55.71	≤54.98	≥54.99 ≤57.05	≥57.06	≤52.90	≥52.91 ≤62.59	≥62.60
Fencing	≤52.77	≥52.78	≥56.47	≤53.44	≥53.45	≥59.75	≤51.82	≥51.83	≥62.78



		≤56.46			≤59.74			≤62.77	
Judo	≤50.76	≥50.77 ≤54.43	≥54.44	≤53.58	≥53.59 ≤59.60	≥59.61	≤57.01	≥57.02 ≤60.20	≥60.21
Soccer	≤52.78	≥52.79 ≤56.45	≥56.46	≤53.58	≥53.59 ≤59.59	≥59.60	≤57.01	≥57.02 ≤63.41	≥63.42
Speed skating	≤53.88	≥53.89 ≤56.90	≥56.91	≤56.75	≥56.76 ≤58.46	≥58.47	≤61.26	≥61.27 ≤62.19	≥62.20
Swimming	≤49.51	≥49.52 ≤58.67	≥58.68	≤58.46	≥58.47 ≤60.69	≥60.70	≤58.26	≥58.27 ≤62.03	≥62.04
Table Tennis	≤54.49	≥54.50 ≤60.10	≥60.11	≤56.87	≥56.88 ≤60.48	≥60.49	≤60.31	≥60.32 ≤62.98	≥62.99
Tae kwon do	≤53.85	≥53.86 ≤57.58	≥57.59	≤55.63	≥55.64 ≤58.98	≥58.99	≤57.15	≥57.16 ≤60.94	≥60.95
Volleyball	≤52.75	≥52.76 ≤56.30	≥56.31	≤55.69	≥55.70 ≤59.18	≥59.19	≤55.39	≥55.40 ≤62.81	≥62.82
Water polo	≤44.83	≥44.84 ≤54.09	≥54.10	≤50.88	≥50.89 ≤58.74	≥58.75	≤54.33	≥54.34 ≤61.09	≥61.10
Weightlifting	≤44.23	≥44.24 ≤52.46	≥52.47	≤47.84	≥47.85 ≤54.27	≥54.28	≤51.70	≥51.71 ≤58.93	≥58.94
Wrestling and Greco-Roman	≤51.37	≥51.38 ≤60.79	≥60.80	≤51.43	≥51.44 ≤61.81	≥61.82	≤55.77	≥55.78 ≤63.20	≥63.21

Table 5. Evaluation profile for aerobic power in female athlete's group in the 20 m shuttle run test test ($VO_2\text{max}$: $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) by biobanding

Sports	Before the PHV			During the PHV			After the PHV		
	low	Average	high	low	Average	high	low	Average	high
Athletics	≤42.39	≥42.40 ≤47.80	≥47.81	≤45.33	≥45.34 ≤51.13	≥51.14	≤46.93	≥46.94 ≤54.53	≥54.54
Basketball	≤35.35	≥35.36 ≤40.91	≥40.92	≤50.00	≥50.01 ≤55.11	≥55.12	≤49.49	≥49.50 ≤54.75	≥54.76
Fencing	≤39.61	≥39.62 ≤44.87	≥44.88	≤41.72	≥41.73 ≤45.48	≥45.49	≤41.64	≥41.65 ≤48.52	≥48.53
Judo	≤42.91	≥42.90 ≤45.30	≥45.31	≤43.19	≥43.20 ≤47.28	≥47.29	≤46.64	≥46.65 ≤49.30	≥49.31
Soccer	≤40.79	≥40.80 ≤44.10	≥44.11	≤41.79	≥41.80 ≤45.10	≥45.11	≤44.72	≥44.73 ≤47.03	≥47.04
Speed skating	≤38.31	≥38.32 ≤41.02	≥41.03	≤40.81	≥40.82 ≤43.57	≥43.58	≤40.41	≥40.42 ≤49.36	≥49.37
Swimming	≤35.72	≥35.73 ≤42.48	≥42.49	≤36.30	≥36.31 ≤44.82	≥44.83	≤38.88	≥38.89 ≤47.92	≥47.93
Table Tennis	≤38.02	≥38.03 ≤42.83	≥42.84	≤41.36	≥41.37 ≤44.73	≥44.74	≤40.04	≥40.05 ≤48.58	≥48.59
Tae kwon do	≤39.82	≥39.83 ≤43.27	≥43.28	≤40.73	≥40.74 ≤44.64	≥44.65	≤43.13	≥43.14 ≤48.14	≥48.15
Volleyball	≤42.31	≥42.32 ≤46.52	≥46.53	≤43.77	≥43.78 ≤47.29	≥47.30	≤44.03	≥44.04 ≤51.31	≥51.32
Water polo	≤34.66	≥34.67 ≤38.42	≥38.43	≤36.22	≥36.23 ≤43.13	≥43.14	≤38.36	≥38.37 ≤44.06	≥44.07
Weightlifting	≤32.39	≥32.40 ≤38.80	≥38.81	≤35.49	≥35.50 ≤40.86	≥40.87	≤36.78	≥36.79 ≤42.56	≥42.57
Wrestling and Greco-Roman	≤40.77	≥40.78 ≤45.62	≥45.63	≤41.18	≥41.19 ≤46.74	≥46.75	≤40.53	≥40.54 ≤49.67	≥49.68

Discussion

The study aimed to determine the profile of aerobic power in young athletes of both sexes belonging to national teams of the state of Barinas-Venezuela according to a specific chronological age range and somatic maturation. Given the range of ages studied (11 to 20 years), it is known that maturation and development processes that occur at various stages of growth, as well as the differentiated bio adaptation factors that occur by the systematic sequence of training loads, depending on sex, orientation of the metabolic demands of each sport and the characteristics of somatic maturation at each stage of chronological age.

PHV refers to the period of most rapid growth in childhood and adolescence and is associated with significant changes in body composition and physical capacity. During this period, adolescents experience an increase in muscle mass (Baxter-Jones & Sherar, 2007; Malina, 1978, 1986; Malina et al., 2004) and bone density (Bailey et al., 2003; Mackelvie & Khan, 2002; Zhang, 2019), which can influence their physical performance, especially in activities requiring aerobic power. $VO_2\text{max}$ is related to sex, body size



and degree of maturity in children and adolescents (Domínguez et al., 2015). It has also been reported that in young people, men have a higher VO_2max than women (Baquet et al., 2006; Landgraff et al., 2021) and that younger and less mature subjects have lower VO_2max values (J. R. Padilla-Alvarado et al., 2018), since a higher degree of maturation, the higher the hormonal load and consequently the neuromuscular performance in young athletes (Almeida-Neto et al., 2022; de Almeida-Neto et al., 2020).

The extant literature combines longitudinal (annual or multi-year follow-up), cross-sectional, and meta-analytical studies examining VO_2max growth during puberty, its temporal coincidence with PHV, and the relative influence of maturation versus training in young athletes. Representative studies employ models to depict individual VO_2max growth curves and to estimate ages at PVP (peak VO_2 growth velocity) and PHV (peak heart rate velocity) for each individual (Geithner et al., 2004; Padilla, 2014), this is consistent with the data in our study.

Some findings indicate that the participation of young people in pubertal growth in endurance sports does not guarantee better performances in VO_2max than those who practice sports with more emphasis on specific motor skills of their sport (Landgraff et al., 2021), which coincides with the present work where it is evident that the group before the PHV does not present much difference for VO_2max between sports, however there are dissimilar values between different sports for the groups during PHV and after PHV. Although it is not the objective of this work to compare sports, it can be pointed out that these differences are probably originated in the degree of maturation and in the characteristics of the energetic demands of each sport, being athletics the one that presents higher values, it could be explained by the high training volumes that are submitted but also to the mechanical development of the race, being a characteristic of training in this sport could represent a mechanical advantage when performing a race test such as the 20m SRT.

In this sense, the findings indicate that, globally, the aerobic power in men was always higher than that achieved by women ($p < .05$) in all sports modalities and age groups, likewise the results were always increasing in relation to the ages ($p < .05$), being greater the differences between the group of 15 to 20 years with respect to the group of 13 to 14.9 years, compared to the difference between the latter and the group of 11 to 11.9 years. The significant intergroup differences were more marked in the male groups ($p < .05$), compared to the female groups. The above coincides with the classical theory that defines a growth in aerobic power as years of training are added during the various stages in the athlete's sporting life.

Aerobic power, which refers to the body's ability to perform prolonged exercise using oxygen, can be affected by physical growth (Malina et al., 2019). Furthermore the development of aerobic power in adolescents is related to increased muscle mass and cardiovascular efficiency, which are often optimized during PHV (Beunen & Malina, 2008; Malina et al., 2004).

In addition, physical training during this stage may further enhance aerobic capacity. It has been suggested that adaptation to aerobic training is most effective in individuals who are in their PHV, as their body is at an optimal developmental stage for improving cardiovascular capacity (Coyle, 1995).

It is important to consider that the relationship between PHV and aerobic power is not linear and may vary according to factors such as genetics, sex and type of physical activity performed. For example, males tend to experience PHV later than females, which may influence their aerobic power development (Baxter-Jones et al., 2002; Malina et al., 2004).

On the other hand, when aerobic power (VO_2max) was analyzed by groups of sports, it was confirmed what has been established in the specialized literature, regarding the higher aerobic metabolic demands in some sports games and combats (soccer, basketball) compared to those sports that depend on strength-speed (karate, speed athletics, volleyball), whose metabolic demands depend to a greater extent on high-energy phosphagen and glycolysis (Brito et al., 2009; Guillén del Castillo & Linares Girela, 2002).

Absolute VO_2max increases markedly in men during and after PHV, reaching values of 4.0–5.0 L/min at 17–20 years of age. In women, it stabilizes around 2.2–2.6 L/min by 14–15 years of age. Relative VO_2max may be maintained or decrease around PHV if the increase in body mass exceeds the gain in oxidative capacity (Mancera-Soto et al., 2022).

Likewise, somatic maturation undergoes processes of change in this age range, some of which are characteristic of biological chronology and others that are stimulated by systematic training loads. Although height is one of the characteristics that are genetically defined, it is also known that its development has well differentiated stages, which are related to the motor manifestations and performance levels in sport. A study that evaluated 268 young males between 10 and 16 years of age ($M = 13.6$; $SD = 1.5$) who were regular participants in a sports initiation program concluded that, among young people of a group of similar ages and with greater advances in maturation, there were higher rates of development of muscle mass and height, but there were no significant differences in most comparisons between the motor performance variables in the different groups considered (Bojikian et al., 2005).

In other sections of the present study, the relationship of aerobic power (VO_2 max) with somatic maturation was analyzed, specifically with the PHV, profiled by Bio-bands from chronological age groups, by sports and sex.

The timing of PHV and its association with performance measures vary across sports and populations. Longitudinal studies show differences in the estimated age of PHV depending on the discipline, so training planning should be tailored to the discipline and maturation profile (Kozieł et al., 2024).

It has also been discussed that the chronology of age has influence on various motor skills such as power (explosive strength), speed and speed of movement, speed, and also in flexibility, and in the consumption of maximum oxygen or aerobic power of soccer players until about 13/14 years, and from this age a kind of prolonged plateau is observed with proximity of 18 years (Leite Portella & De Arruda, 2011). Therefore, the categories elaborated will allow the comparison of groups with similar characteristics and this allow a more objective interpretation of the VO_2 max results estimated by means of the 20 m shuttle run test, taking into account that the sample was intentional because the data collected would only be a reference for other sports and applicable to the group under study, in addition to being a cross-sectional study and lacking control of certain external variables. Therefore, future research is directed to consider these variables mentioned above that may allow strengthening the present research.

Conclusions

The results of this research allow us to conclude that the profiles of aerobic power, considering VO_2 max as a classification criterion, allow categorization of the level of cardiovascular fitness in young athletes of both sexes and sports practiced, with the individualization of age group and level of somatic maturation for the group under study, which can be used in the process of controlling training in athletes on an individual basis.

Finally, this research contributes to proposing cutoff points by sport and level of somatic maturation in young athletes, offering coaches and physical educators a valuable tool for monitoring and controlling the training process.

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Disclosure

The authors declare that they have no conflict of interest in this scientific product.



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