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Aerobic Power Profile in Young Athletes According to Age and Bio Banding

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Abstract: Objectives: VO_2max values can be obtained through direct measurement with the use of laboratory tests or can be estimated indirectly by applying field tests, evaluative cut-off points are also required, which are adjusted to the individual characteristics of the subjects, including the sport discipline practiced. The aim of the present work is to categorize aerobic power in male and female athletes according to specific chronological age ranges and Bio-Bands of somatic maturation in young athletes. **Methods**: A quantitative, cross-sectional, descriptive study was carried out. A total of 613 athletes between 11 and 20 years of age were evaluated. The maximum oxygen consumption was estimated through the 20 m shuttle run test, and the anthropometric variables through the ISAK protocol. The peak heigth velocity was used to establish the somatic maturation bio-bands. For the determination of the aerobic power profile, cut-off points were made with the mean and standard deviation, processed using SPSS 28.0. **Results**: it is observed that the male group presents higher values than the female group, while the athletics subjects of both sexes present higher values for VO_2 max in all age groups and by degree of maturity, with an average of 60 ml.kg.min for males and 51 ml.kg.min for females, with the exception of boys in wrestling and Greco-Roman wrestling from 11 to 12.9 years of age with 57.4 ml.kg.min. **Conclusions**: the cut-off points constructed represent a reference to evaluate the aerobic power and qualify the aerobic physical fitness level of the athletes, according to the sport practiced and the individual characteristics of the subjects.

Keywords: sports; maximum oxygen consumption; somatic maturation; PHV; VO_2 max

1. Introduction

Muscle energy is provided by three mechanisms that act simultaneously, with differences in their power and capacity [1], among them we have the aerobic power that has been defined as the maximum capacity of oxygen consumption (VO2max) of a subject [2] and is directly related to the maximum energy production in the unit of time, at the expense of aerobic metabolism. VO_2max is the equivalent for the metabolic manifestation of the concept of aerobic power and its values are expressed in absolute terms (lts/min or ml/min) and in relative form (ml/kg/min), highlighting that this relative form of expressing VO_2max per kg provides information on body composition and cardiovascular fitness [3].

VO_2max values can be obtained through direct measurement with the use of laboratory tests that require the use of gas analyzers either with mixing chamber technology or Breath-by-Breath systems depending on the objective [4,5], also using cost important 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, whichever is chosen, usually the protocols are designed to last approximately between 8 and 14-16 minutes.

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On the other hand, VO_2max 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 VO2max is one of the most important tests of cardiorespiratory fitness.

However, it is not enough just to estimate or measure VO_2max, as evaluative cut-off points 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 [6–8], 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.

Another fundamental aspect is somatic maturation which has demonstrated its association with aerobic performance in young athletes [9], in order to mitigate the impact of maturation on performance the degree of maturation should be monitored [10], since decreases or increases in performance may occur according to the degree of maturation, therefore, the intervention plan should be adjusted taking into account this aspect. Therefore, using VO_2max assessment strategies according to bio-banding, considering interindividual differences in the state of maturity among young people of the same chronological age [11], the evaluation of physical fitness will be more objectively assessed.

Moreover, in consideration that it has been recommended that fitness monitoring is necessary to inform decision making, and the application of international fitness tests using valid, reliable and standardized measures [12], in this sense the 20 m shuttle run test, represents a suitable instrument to characterize aerobic power and compare between populations.

The 20 m shuttle run test is one of the most used in practice by coaches and researchers when it comes to estimating VO2 max in healthy youth populations, considered a broad health indicator for population health surveillance in children and youth (Lang, 2018), in a review it was determined that South American countries have worse performances, associated with income inequality assessed by Gini index [13], however in that same work they indicate that African countries present better performances, although a related standard [14] is frequently used to classify the population of children and adolescents [15], it should be taken into account that it is very likely that the athletic levels of the population evaluated in South America were low, and also 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, the question arises: What will be the appropriate cut-off points for evaluation of VO2 max in young athletes?

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 to categorize aerobic power in male and female athletes according to specific chronological age ranges and Bio-Bands of somatic maturation in young athletes.

2. Materials and Methods

2.1. Design and Participants

The study is approached from the quantitative, in a non-experimental design, with a descriptive-relational 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. The ages were

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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.

All were previously informed, and their participation was authorized by their representatives in the case of minors. The study was approved 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.

2.2. Procedures

Protocols for the estimation of aerobic power (VO_2max) and somatic maturation bio-bands.

The 20 m shuttle run test [16,17] was used to estimate the aerobic power being recommended for athletes in the selected ages [18] , with a previous practice of familiarization by the subjects to be evaluated. The data was collected in a period of five (5) years, carried out during the evaluation and control processes programmed by the coaches of each of the sports. The formula used to estimate VO_2max is validated to evaluate young people and adolescents [19]. The protocol of the International Society for the Advancement of Kinanthropometry was used for the measurement of anthropometric variables [20] 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 by means of predictive equations for the evaluation of somatic maturation adjusted to the Venezuelan population [21]. Once the Peak Height Velocity (PHV) was calculated, three (3) groups were generated: before PHV (< - 0.5 years), during PHV (≥ - 0.5 ≤ + 0.5 years) and after PHV (> + 0.5 years).

2.3. Statistical Model

The data was processed with the Statistical Package for the Social Sciences (SPSS-Statistical Package for the Social Sciences) version 28.0 for Windows ©. 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 [22]. Once the distribution was corroborated, 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 ± 1 standard deviation) and above average (mean plus 1 standard deviation).

3. Results

Aerobic power assessment profiles by age ranges

Tables 1 and 2 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 Vo2max (ml/kg/min), 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.min for men and 51.5 ml.kg.min 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.min and in women are the athletes with 49.2 ml.kg.min.

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Table 1. Evaluation profile for aerobic power in male athlete's group in the 20 m shuttle run test (VO2 max=ml/kg/min) by age.

	[11-12,9] Years			[13 - 14,9] Years			[15-20] Years		
	below	Average	Avove	below	Average	Avove	below	Average	Avove
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
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
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
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
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
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
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
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
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
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
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 51,15	≥51,16	46,88≤	46,89 56,64	≥56,65	48,78≤	48,79 58,29	≥58,30
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
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
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 2. Evaluation profile for aerobic power in female athlete's group in the 20 m shuttle run test (VO2 max=ml/kg/min) by age.

	[11-12,9] Years			[13 - 14,9] Years			[15-20] Years		
	below	Average	Avove	below	Average	Avove	below	Average	Avove
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
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
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
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
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
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
Water polo	32,49≤	32,50	≥39,26	35,40≤	35,41	≥39,30	36,64≤	36,65	≥42,36

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	[11-12,9] Years			[13 - 14,9] Years			[15-20] Years		
	below	Average	Avove	below	Average	Avove	below	Average	Avove
Basketball	38,67≤	39,25 38,68 41,11	≥41,12	43,62≤	39,29 43,63 50,53	≥50,54	46,58≤	42,35 46,59 51,84	≥51,85
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
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
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
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
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 3 and 4), it is observed that the male group of athletics presents values over 60 ml.kg.min in the 3 categories; on the other hand, in the female group it is observed that with 47, 51 and 54 ml.kg.min, the groups before during and after the PHV for athletics present the best performance.

Table 3. Evaluation profile for aerobic power in male athlete's group in the 20 m shuttle run test test (VO2 max=ml/kg/min) by biobanding.

	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
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
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
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
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
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
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
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
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
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
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 56,46	≥56,47	53,44≤	53,45 59,74	≥59,75	51,82≤	51,83 62,77	≥62,78
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
Judo	50,76≤	50,77	≥54,44	53,58≤	53,59	≥59,61	57,01≤	57,02	≥60,21

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	Before the PHV			During the PHV			After the PHV		
	low	Average	high	low	Average	high	low	Average	high
Wrestling and Greco-Roman	51,37≤	54,43 51,38 60,79	≥60,80	51,43≤	59,60 51,44 61,81	≥61,82	55,77≤	60,20 55,78 63,20	≥63,21

Table 4. Evaluation profile for aerobic power in female athlete's group in the 20 m shuttle run test test (VO2 max=ml/kg/min) by biobanding.

	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
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
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
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
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
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
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
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
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
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
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
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
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

4. 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 the 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 and bone density, which can influence their physical performance, especially in activities requiring aerobic power. VO2max is related to sex, body size and degree of maturity in children and adolescents [23] it has also been reported that in young people, men have a higher VO2max than women [24,25] and that younger and less mature subjects have

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lower VO2max values [3], being that the higher the degree of maturation, the higher the hormonal load and consequently the neuromuscular performance in young athletes [26,27].

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 [25], 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.

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 [11], furthermore the development of aerobic power in adolescents is related to increased muscle mass and cardiovascular efficiency, which are often optimized during PHV [28,29].

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 [30].

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 [29,31].

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 [32,33].

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 [34].

In other sections of the present study, the relationship of aerobic power (VO_2max) with somatic maturation was analyzed, specifically with the PHV, profiled by Bio-bands from chronological age groups, by sports and sex.

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 [35]. Therefore, the categories elaborated will allow the comparison of groups with similar characteristics and thus allow a more objective interpretation of the VO2max results estimated by means of the 20 m shuttle run test.

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5. Conclusions

The results of this research allow us to conclude that the profiles of aerobic power when considering VO2max as a classification criterion, allow us to categorize 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.

Author Contributions: JP: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft. JLM; Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – review & editing. MC; Formal analysis, Funding acquisition, Investigation, Methodology, Resources, Software, Validation, Visualization, Writing – original draft.

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Institutional Review Board Statement: The study was approved by the Ethics Committee of the Observatory of Research in Physical Activity and Sports Sciences (OICAFD) of the Nation-al Experimental University of the Western Plains Ezequiel Zamora (UNELLEZ) and international standards established in the Helsinki Declaration for the development of re-search on human beings, with approval number 0043 dated January 15, 2023.

Informed Consent Statement: All were previously informed, and their participation was authorized by their representatives in the case of minors.

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Data Availability Statement: The data and materials this study is based on are available from the corresponding authors, JP; JLM.

Conflicts of Interest: The authors declare that they have no known competing financial interests.

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