INTRODUCTION

The number of children and youths participating in high-level competitive sports is on the rise, and it is a fact that during prepubescence, and especially at maturation, many somatic, functional and physiological changes occur which increase the biological variability among children of the same chronological age. (1), (2) Despite this, the majority of studies focus on chronological age groups, even though classification on the basis of chronological age, needless to say, is of limited utility as an indicator of maturity status during this period of life. (3) On the other hand, according to several authors, different levels of performance within a given age group are often the result of the variations observed in the timing and tempo of these changes, which produce different strength, speed and endurance outcomes. (4)

Many studies have assessed the physical characteristics of athletic populations at different levels of competition, from Olympic to national level. The results of these studies suggest that a particular profile is success associated with performance. (5) On the other hand, data for Latin American child and adolescent swimmers are less often considered and hence information is limited. What is more, although maturation status may contribute to elite performance, and, in the case of swimming, the bodies of adolescent participants in this sport are still in the developmental phase, very little information is provided on the physical structure of young Latin American swimmers. However, the assessment of sexual maturation is no easy task, especially not in the presence of limitations that jeopardize a proper physical, assessment. Accordingly, the present study was directed at the formulation of a classification rule, based on a set of anthropometric variables, to produce an approximation of maturation categories that could serve as a guide for coaches.

METHODS

Subjects

The sample analyzed here was part of a project on the growth and nutritional status of young Venezuelan swimmers, a larger collaborative research project carried out by the Central University of Venezuela and Fundacredesa and entitled, “Assessment of Growth, Nutritional Status, Food Intake and Socioeconomic Conditions of Young Venezuelan Swimmers”. (6). The athletes who volunteered to enroll on the study were members of the Miranda State team, which currently holds the national swimming championship. Data were collected mid-season. Younger swimmers trained in one two-hour session a day, five days a week, while older swimmers trained in daily two-hour sessions, six days a week. About 60% of the athletes sampled competed in regional and/or national meets and a smaller group was already participating in international events. Testing procedures were fully explained and informed consent was obtained from parents in writing. We selected for consideration just one hundred and fifteen male child and adolescents swimmers (aged 7-17) from the total cross-sectional sample of the whole project, as meeting the established criteria based on a complete set of anthropometric variables and the assessment of sexual maturation.

Thirty-five anthropometric variables were selected for the study, and their values measured in accordance with the ISAK guidelines. (7) Data was collected for all participants on the following anthropometric variables. There were four body size variables, these being stretch stature, body mass, sitting height and arm span, and eight subcutaneous fatness variables, namely triceps, subscapular, biceps, iliac crest, supraspinal, abdominal, front thigh and medial calf skinfolds. Indicators of skeletal robustness comprised seven length measurements, acromiale-radiale (arm length), radiale-stylion (forearm length), midstylion-dactylion (hand length), trochanterion-tibiale laterale, tibiale laterale, tibiale mediale-spyrion tibiale and foot and seven breadth measuremenst, biacromial, biiliocristal, transverse chest, anterior-posterior chest depth, biepicondilar humerus, wrist and biepicondilar femur. There were nine variables indicative of relative muscularity, all girths, specifically relaxed arm, arm flexed and tensed, forearm, wrist, chest, waist, gluteal (hip), thigh and calf circumferences.

Stretch stature, sitting height and arm span were determined to the nearest 0.1 cm. and body mass to the nearest 0.1 kg., employing a portable stadiometer, a wall scale Brocca plane and a portable scale, respectively. Skinfold thicknesses were measured using SlimGuide calipers (10 g/mm2 constant pressure), a widely-used type of plastic caliper that gives results similar to the Harpenden (8). These dimensions were taken in duplicate, and the means of the trial values entered on the anthropometric datasheet. If a third trial was required, the median of the three measures was taken as the representative value. Direct and projected lengths were measured to the nearest 0.1 cm using an anthropometer and a segmometer respectively. Breadths and circumferences were also recorded to the nearest 0.1 cm with an anthropometer and a Lufkin steel tape, respectively.

Measurements were taken by one uncertified anthropometrist, and one Level 1 and one Level 2 ISAK certified anthropometrist, all supervised by an ISAK Level 3 Instructor (BP), who also measured many of the subjects. Prior to the project all measurers were found to meet the ISAK criteria for technical errors of measurement of <5% for skinfolds and <1% for all other variables. (9), (10)

The sample was subdivided on the basis of

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Tanner's (11) sexual maturation stages of genitalia (G1-5) into the three categories posited by Nicoletti: Preprepuberty (G1), Initial puberty (G2-3) and Advanced puberty (G4-5)., (12) Assessment of sexual maturation was based on clinical examination. Maturity rate was monitored by a physician (CM-T). The development of secondary sex characteristics such as development of the genitalia has been summarized in the five-stage scales of the Marshall-Tanner method. (13) Therefore, groups were partitioned into the categories of prepuberty (stage 1), characterized for the appearance of male genitalia as in early childhood; initial puberty (stages 2 and 3) for initial and continued development of those organs, and late puberty (stages 4 and 5) as indicative of their continued and adult or terminal development.

Statistical analysis

In order to build a rule for classification based on the identification of anthropometric variables affording greater power for predictive purposes among prepubescents, initial pubescents and advanced pubescents, a forward stepwise discriminant analysis was performed, using increase in hit rate as the selection criterion. (14) The best subset of indicators was selected according to their relative contribution to the proportion of correct classification, both globally and within groups. 95% confidence intervals were estimated for means of the selected variables. Statistical analyses were performed using SPSS software (version 10.0) and SPAD 4.5, with significance set at $p < 0.05$.

RESULTS

Mean anthropometric variables for each maturity group are summarized in Table 1. in general, for the majority of the variables, mean values increase from prepubescence to advanced pubescence as expected. The exception was skinfold measurements, which showed a tendency to diminished. Subscapular skinfolds, however, behaved in line with the other dimensions.

There was a total number of 35 variables, from which stretch stature, triceps and subscapular skinfold, calf and relaxed arm girths, body mass, and forearm and thigh lengths were selected as the best subset of anthropometric variables, in terms of their predictive capabilities. Ranking by stepwise selection is presented in Table 2.

This set of variables produced a high aggregate apparent hit rate of 87%. The hit rate increases through the maturity groups from 80% in prepuberty to 93% in advanced puberty. During the selection process it was observed that stretch stature, triceps and subscapular skinfolds accounted for 75% of correctly classified prepubescents. When calf circumference, relaxed arm and body mass were included the hit rate reached 80%. All variables except lengths were required to reach 83% correct classification of initial pubescents. Finally, the most powerful variables for discriminating advanced puberty were stretch stature and triceps skinfold, which identified 89%.

Two linear discriminant functions (LDF1 and LDF2) capable of separating sexual maturation groups emerged when Wilks' lambda test (p=0.000) was applied. These functions were able to account for a substantial proportion of the differences between groups, as indicated by their squared canonical correlations (0.66 and 0.39 respectively). The resulting correlation structure is shown in Table 3.

These results indicate that the scores from LDF1 are basically made up of stretch stature, body mass, forearm length, thigh length, relaxed arm circumference and calf circumference measurements. LDF1 may account for separation of prepuberty and advanced puberty due to important differences in the discriminant variables. The LDF2-associated separation of initial puberty from the other groups may be attributed to the adiposity level in the triceps skinfold (Figure 1).

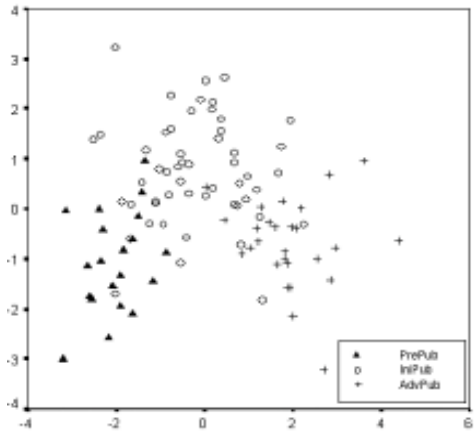

Figura 1. Canonical Discriminant Functions LDF Plot.

Table 4 summarizes the 95% confidence intervals for means of the eight variables identified in the discriminant analysis, by prepubescents, initial pubescents and advanced pubescents. According to these results, two variables for body size, two for subcutaneous fatness, two for skeletal robustness and two for relative muscularity suffice to guide coaches when placing young swimmers into the categories that best approximate the variability of maturation. Only triceps and subscapular skinfolds present overlapping intervals in the three categories, which is characteristic of the skinfolds in these athletes.

DISCUSSION

Despite the enormous amount of descriptive material available on the physiques of athletes, data concerning maturation in young Venezuelan competitive swimmers have not been collected to the

Table 1. Anthropometric variables (mean ± standard deviation) by maturity status

Variables	Preprepuberty (n=20)	Initial prepuberty (n=53)	Advanced prepuberty (n=27)
		Body Size	
Stretch stature (cm)	136.4 ± 6.7	152.6 ± 10.8	170.0 ± 7.9
Body mass (Kg)	31.6 ± 5.1	44.2 ± 9.8	58.5 ± 10.3
Sitting height (cm)	71.3 ± 2.6	77.8 ± 6.4	86.8 ± 4.1
Arm span (cm)	137.7 ± 7.8	156.6 ± 13.1	174.7 ± 10.9
		Subcutaneous Fatness	
Triceps skinfold (mm)	8.1 ± 3.3	9.2 ± 2.7	7.0 ± 2.5
Subscapular skinfold (mm)	6.1 ± 2.2	6.3 ± 1.4	7.1 ± 1.6
Biceps skinfold (mm)	5.1 ± 2.3	5.2 ± 1.7	3.7 ± 0.7
Iliac crest skinfold (mm)	9.3 ± 5.0	10.2 ± 3.8	9.4 ± 3.7
Supraspinal skinfold (mm)	5.8 ± 3.2	6.2 ± 2.4	6.0 ± 1.9
Abdominal skinfold (mm)	8.3 ± 4.3	9.6 ± 3.8	8.9 ± 3.3
Front thigh skinfold (mm)	12.2 ± 3.6	13.5 ± 4.3	10.4 ± 2.4
Medial calf skinfold (mm)	8.7 ± 3.0	10.3 ± 3.7	8.2 ± 1.9
		Skeletal Robustness	
		Lengths	
Arm length (cm)	25.5 ± 1.8	28.7 ± 2.3	31.9 ± 2.1
Forearm length (cm)	20.0 ± 1.3	23.3 ± 2.2	26.1 ± 2.5
Hand length (cm)	15.6 ± 1.0	17.7 ± 1.5	19.1 ± 1.0
Trochanterion-tibiale laterale length (cm)	33.3 ± 3.5	36.9 ± 3.4	41.7 ± 3.3
Tibiale laterale length (cm)	40.9 ± 7.4	43.1 ± 3.8	46.8 ± 2.5
Tibiale mediale-spyrion tibiale length (cm)	30.5 ± 2.1	34.4 ± 2.9	38.6 ± 2.6
Foot length (cm)	21.5 ± 1.6	23.8 ± 1.7	25.9 ± 1.4
		Breadths	
Biacromial breadth (cm)	30.0 ± 1.9	33.3 ± 3.4	38.4 ± 2.6
Biliocristal breadth (cm)	19.6 ± 1.9	22.5 ± 2.4	24.8 ± 2.8
Transverse chest breadth (cm)	20.4 ± 1.5	23.3 ± 2.6	26.0 ± 1.9
Anterior-posterior chest depth (cm)	14.0 ± 1.3	16.0 ± 1.9	18.2 ± 1.8
Biepicondilar humerus breadth (cm)	5.5 ± 0.4	6.2 ± 0.4	6.8 ± 0.4
Wrist breadth (cm)	4.4 ± 0.4	4.9 ± 0.4	5.4 ± 0.4
Biepicondilar femur breadth (cm)	8.4 ± 0.5	9.2 ± 0.6	9.6 ± 0.5
		Relative Muscularity	
Relaxed arm (cm)	20.0 ± 2.2	23.3 ± 2.7	26.8 ± 2.9
Arm flexed and tensed (cm)	21.3 ± 2.3	24.7 ± 2.9	28.8 ± 3.1
Forearm (cm)	19.5 ± 1.4	22.0 ± 2.0	24.5 ± 2.1
Wrist (cm)	13.1 ± 0.6	14.6 ± 1.2	15.8 ± 0.9
Chest (cm)	67.6 ± 4.6	76.4 ± 7.5	87.1 ± 6.7
Waist (cm)	58.4 ± 3.6	64.8 ± 5.0	71.0 ± 6.4
Gluteal (hip) (cm)	67.6 ± 4.4	77.2 ± 7.3	85.0 ± 5.8
Thigh (cm)	40.2 ± 3.4	46.3 ± 4.8	49.8 ± 4.2
Calf (cm)	26.7 ± 2.0	30.5 ± 2.9	

Table 2. Stepwise ordering of anthropometric variables by prediction capability

Variables	*Final rank*	*Step*						
		1	*2*	*3*	*4*	*5*	*6*	*7*
stretch stature	1	1	1	1	1	1	1	1
triceps	2		2	2	2	2	2	2
subscapular	3			3	3	3	3	3
Calf circumf.	4				4	4	4	4
relaxed arm	5					5	5	5
body mass	6						6	6
forearm length	7							7
thigh length	8							
%Clas_Global	87	72	76	78	78	79	83	83
%Clas_Prepub	80	65	70	75	75	75	80	80
%Clas_InitPub	87	72	72	76	76	79	83	79
%Clas_AdvPub	93	78	89	85	85	82	85	93

Table 3. Discriminant functions (LDF1, LDF2)

Structure Matrix		
	Function	
Variable	LDF1	LDF2
Stretch stature	0.898**	0.045
Body mass	0.737**	0.009
Forearm length	0.706**	0.147
Relaxed arm	0.643**	0.034
Thigh length	0.636**	-0.056
Calf circumference	0.609**	0.214*
Subscapular skinfold	0.167*	-0.105
Triceps skinfold	-0.133	0.340**
Canonical Correlation	0.810**	0.628
Wilk's Lambda	0.208**	0.605*

Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions.
Variables ordered by absolute size of correlation within function
**Significant at the 0.01 level
*Significant at the 0.05 level

Table 4. 95% confidence interval for means of anthropometric characteristics that discriminate maturity status

Variables	*Prepubescents(n= 20)*		*Initial pubescents(n=53)*		*Advanced pubescents (n=27)*	
	lower bound	upper bound	lower bound	upper bound	lower bound	upper bound
			Body Size			
Body mass (Kg.)	29,2	34,0	41,5	46,9	54,4	62,6
Stretch stature (cm.)	133,2	139,5	149,6	155,5	166,8	173,1
			Subcutaneous Fatness			
Triceps skinfold (mm.)	6,6	9,7	8,4	9,9	6,1	8,0
Subscapular skinfolds (mm.)	5,1	7,2	5,9	6,7	6,5	7,8
			Skeletal Robustness			
			Lengths			
Forearm length (cm.)	19,0	21,1	22,67	24,0	25,7	28,0
Thigh length (cm)	31,6	34,9	35,9	37,8	40,4	43,0
			Relative Muscularity			
Relaxed arm (cm.)	19,0	21,1	22,6	24,0	25,7	28,0
Calf (cm.)	25,7	27,6	29,7	31,3	32,2	33,9

requisite level of detail. The present study showed that a reduced number of variables could be taken into account for the classification of swimmers within the maturation process. Changes in the relationships between the variables over time affect the weight that each variable brings to the discriminant analysis.

Based on the results above, eight measurements could be used to classify these swimmers in groups reflecting maturation categories. As elicited in Table 2, stretch stature is by itself the most predictive capability variable. Differences in stature are in line with the biological variability of growth among maturation groups. Stature is the most commonly used indicator of somatic maturation, as it marks an onset of physical development during puberty. Most other indicators, such as changes in body dimensions, proportions and composition, follow the pace set by this variable. Swimmers generally exhibit greater height than the average population, in conjunction with earlier maturation. (15) This fact was particularly true among initial and advanced pubescents, and is in agreement with the tendency in the general population of high-income boys and girls toward earlier maturation that has already been observed in the Caracas longitudinal study. (16) Furthermore, based on previous studies, (17) it will be noted that Venezuelan swimmers were taller and heavier in comparison with Cuban and Mexican swimmers.

Additionally in this group of swimmers it is important to note that an important marginal increase in apparent hit rate when triceps and subscapular skinfolds are taken in conjunction with good development of the musculature of the extremities, represented by relaxed arm and calf circumference. Data reported by Arenas et al. (18) for the general Venezuelan population of similar age and by Leone et al. (19) in female swimmers, suggest the important role played by this last variable in the characterization of groups. On the other hand, as growth proceeds in these children and youths, their upper body fat increases.

Characterizing variables were successfully identified that could separate the three maturity status groups. The highest prediction capabilities in all categories were offered by stretch stature, triceps and subscapular skinfolds, which were found to be the dominant variables, producing an impressive hit rate (75%) in prepubescents. In order to reach the highest hit rate (80%) in the aforementioned group, calf circumference, relaxed arm and body mass were also required. This set of variables were also essential to attain 83% correct classification in initial pubescents. In contrast, just stretch stature and triceps skinfold result in a hit rate of 89% for advanced pubescents. The eight variables selected by the discriminant analysis process were sufficient to attain 80%, 87% and 93% apparently correct classification of prepubescents, initial pubescents and advanced pubescents respectively.

Since discriminant analysis was taken as the decision rule, if the variables used for this analysis are available, then a simple program can be used to estimate the probability that a subject will fall into a given group, prepubescence, initial pubescence, or advanced pubescence. In practice, however, this information will very probably not be available, and so means and their confidence intervals can be used as a reference for estimating maturation categories.

While coaches should consider the potential genetic predisposition of young athletes in talent identification and development programs, it is also necessary that maturity indicators, which are partly related to the endocrinological changes of puberty, be taken into account. Compelling data (20), (21), (22), (23) indicate that biological age rather than chronological age is a better predictor of physical performance, since a given bone age can correspond to a wide range of chronological ages.

CONCLUSIONS

There can be no doubt that the growth and maturation process, together with other sets of variables, is essential for the identification of athletic talents as changes occur, both in physical structure and performance. It may be concluded from this study that - as determined in this particular sample - certain anthropometrical variables have a specific weight to separate groups of maturity status. The present paper provide criteria that can guide coaches in the classification of swimmers by certain biological characteristics, which will bring the training they provide more into line with the biological status of specific athletes.

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