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# Somatic Maturity and Physical Performance in Male Youth Players from a Professional Soccer Academy

## Madurez Somática y Rendimiento Físico en Jugadores Juveniles Masculinos de una Academia de Fútbol Profesional

**Luis Enrique Carranza-García[1,2]; Natanael Cervantes-Hernández[3]; Mario Domínguez-Sosa[1,2]; Marcela Alanís-Flores[2,4]; Ricardo López-García[1]; Aldo Vasquez-Bonilla[5] & Luis Alberto Flores[3]**

**CARRANZA-GARCÍA, L. E.; CERVANTES-HERNÁNDEZ, N.; DOMÍNGUEZ-SOSA, M.; ALANÍS-FLORES, M.; LÓPEZ-GARCÍA, R.; VASQUEZ-BONILLA, A. & FLORES, L. A.** Somatic maturity and physical performance in male youth players from a professional soccer academy. *Int. J. Morphol., 42(2)*:429-436, 2024.

**SUMMARY:** The aim was to analyze the relationship between somatic maturation and physical performance in male youth soccer players belonging to a professional Mexican academy. In 121 male soccer aged 11 to 16 years from a professional academy the peak height velocity (PHV), percentage of adult height (PAS), jump capacity, sprint, intermittent speed and muscle mass were estimated. ANOVA was conducted to compare performance variables among maturity somatic categories and percentiles were calculated based on maturity offset using LMS method. Furthermore, a general linear model was employed to determine the explanatory variables for performance. Post-PHV soccer players demonstrated superior physical performance across several tests compared to Pre-PHV ($p<0.001$) and Circa-PHV ($p<0.001$) players. The smoothed percentile values of performance tests, based on somatic maturation, indicated progressive performance enhancement as individuals approached PHV (-2 to 2 years from PHV) ($p<0.005$). PHV was associated with jump capacity ($p<0.001$) and intermittent speed ($p=0.007$) while PAS was associated with time in sprint ($p=.0004$). In conclusion PHV and PAS explained better performance than chronological age, body composition characteristics, injuries, or training factors.

**KEY WORDS: Peak Height Velocity; Growth spurt; Somatic maturity; Soccer players; Physical fitness.**

## INTRODUCTION

Chronological age is commonly used to cluster soccer players in inferior categories to prescribe training loads or to use relative age from quartile birth as a potential indicator in the identification of sports talent; however, it has been observed that biological maturation may be a better variable than chronological age to explain sport performance in male soccer players (Radnor *et al*., 2021).

One of the most widely used indicators of biological maturation is the Peak Height Velocity (PHV), which refers to the maximum velocity of growth in stature and has been used to characterize developments in performance relative to the adolescent growth spurt and indicates the timing of somatic maturation (Malina *et al*., 2004). In recent years, it has been the subject of study to identify PHV in young players in individual sports such as tennis, gymnastics and swimming as well as in team sports such as basketball, baseball, handball and soccer due to their significant association with physical performance.

From a physiological point of view, during PHV there is an increase in height of about 8-9 cm in girls and about 10-11 cm in boys, due to the activity of the hypothalamic-pituitary axis that stimulate sex hormones and the release of growth hormone and insulin-like growth factor type 1 (IGF-1); besides propitiating an increase in muscle mass in males of approximately 10 % (Chulani & Gordon, 2014), which indicates a sensitive phase to induce training loads oriented to hypertrophy, power and muscle strength (Murtagh *et al*., 2017). It has been observed that adolescents who have passed the PHV (Post-PHV) present better muscle power, speed and aerobic capacity than adolescents who are during the PHV (Circa-PHV); and in turn the Circa-PHV, present better performance in those indicators than those who have not reached the PHV (Pre-PHV) (Murtagh *et al*., 2017).

[1] Universidad Autónoma de Nuevo León, Facultad de Organización Deportiva, Monterrey, Nuevo León, México.
[2] Club Tigres, Universidad Autónoma de Nuevo León, México.
[3] Universidad Autónoma de Chihuahua, Facultad de Ciencias de la Cultura Física, Chihuahua, Chihuahua, México.
[4] Facultad de Salud Pública y Nutrición, Universidad Autónoma de Nuevo León, México.
[5] Facultad de Ciencias del Deporte, Universidad de Extremadura, Comunidad Autónoma de Extremadura, España.

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However, the timing at which somatic maturation or PHV occurs in soccer players of the same chronological age may vary considerably. In a study conducted by Parr *et al*. (2020), in English soccer players they observed a three-year variation in the age of occurrence of PHV (APHV), appearing between 12.5 to 15.5 years. On the other hand, an APHV of 13.8 years in male soccer player with a standard deviation of 1.0 has been observed in longitudinal data, indicating that a subject considered as an on-time maturer presents an APHV of 13.8±1.8 years, an early maturer an APHV <12.8 years and a later maturer an APHV >14.8 years (Malina *et al*., 2012).

It has been reported that early maturers manifests superior physical performance to late maturers, however, when late maturer reach their full maturity process, the physical advantage of early maturer could be attenuated or even reversed. Based on this, APHV and somatic maturation status may be used as a reference for coaches or talent scouts to make decisions in the adjustment of training loads, or in the identification and selection of potential sports talents (as well as, in the continuity of players in soccer academy teams that seek to play in the first professional division (Dodd & Newans, 2018).

On the other hand, Myburgh *et al*. (2016), suggests that studies focused on the study of PHV, should not be generalized to populations from different countries, due to the variability of tempo and timing of biological maturation induced by environmental and genetic factors, which in turn vary between different contexts and sport disciplines. In soccer, the studies conducted on somatic maturation have been mainly in European (Ramirez-Campillo *et al*., 2023), Asian (Nobari *et al*., 2022) and South American soccer players but not in Mexican population, so the present study would represent the first approach in the study of biological maturation in Mexican soccer players. Therefore, the objective of the present study is to analyze the relationship between somatic maturation and performance in male soccer players from 12 to 16 years belonging to a professional Mexican academy.

## MATERIAL AND METHOD

**Participants.** The present study presents a cross-sectional descriptive, comparative and correlational design. A total of 121 male soccer players aged 11 to 16 years (age: 13.9 ± 1.63 years; height: 163.9 ± 12.4 m; BMI 20.4 ± 2.5kg/m2) belonging to the different youth categories of a first division professional soccer team in Mexico, were evaluated. All players accepted and parents signed the informed consent form, and the parents or guardians signed the informed consent form. The study protocol was performed in accordance with the ethical standards from the Declaration of Helsinki in 1975 and approved by the local ethics committee and with the approval by the local ethics committee of the Autonomus of Nuevo Leon, Mexico, (Protocol Number: without folio number).

**Protocol.** The first day in the morning anthropometric measurements were taken, in the afternoon explosive strength in lower limbs was evaluated with 3 different vertical jumps, squat jump (SJ), countermovement jump (CMJ), and Abalakov jump (ABK), sprint capacity in 40 m (splits at 10, 20, 30 m), the following day in the morning intermittent speed was evaluated with the 30-15 IFT. In addition, parental height, training frequency, training volume, and playing position were collected. The entire sample was evaluated in the same week.

**Anthropometric measurements.** Anthropometric measurements were performed by nutritionists and personnel certified by the International Society for Advancement in Kineanthropometry (ISAK). Players were summoned first thing in the morning, fasting no more than 4 hours and dressed appropriately. Basic weight measurements were taken with the Tanita BC-418 scale (0 - 200 kg ± 0.1 kg), height and sitting height with the Seca 213 stadiometer (20 - 205 cm ± 1 mm). Sitting height was measured of the trunk of the body from the buttocks to the top of the head when the subject is sitting upright, was used a box of 40 cm high to record this measure. Perimeters were taken from the relaxed and contracted arm, waist and calf medial with a metallic tape measure (0 - 200 cm, Lufkin). The Harpenden plicometer (0 - 80 ± 0.2 mm; Harpenden Skinfold Caliper, John Bull British Indicators®, England) was used to measure the triceps, subscapular, iliac crest, supraspinale, abdominal, front thigh and medial calf skinfolds. Afterward, the brachial muscle area was estimated using the method by Heymsfield *et al*. (1982) recommended for youngs:

$$.AMB = \frac{[Arm\ circumference - (\pi * tricipital\ skinfold)]^2}{4 * \pi} - 10.$$

The total muscle mass was estimated using the formula proposed by Lee *et al*. (2000):

$$Total\ muscle\ mass\ (kg) = Height\ cm * [0.0264 + (0.0029 * AMB)]$$

### Somatic maturity

**Maturity offset.** Maturity offset (MO) was estimated using the predictive equation established by Mirwald *et al*. (2002), as follows: in boys, maturity offset (MO-Mirwald) = - 9.236 + 0.0002708-leg length and sitting height interaction - 0.001663-age and leg length interaction + 0.007216-age and sitting height interaction + 0.02292-weight by height ratio*100; and by the Moore modified equation (Moore *et al*., 2015): maturity offset (MO-Moore) = -7.999994 + [0.0036124 * (age * height)]. Subsequently, the age at which the Peak Growth Velocity (APHV) will be reached was estimated. Soccer players were classified as Circa-PHV who presented a MO ±0.5 years, as Pre-PHV who presented a MO <-0.5 years, and as Post-PHV with a MO >0.5 years.

**Percentage of adult height.** Adult height was predicted using the method proposed by Khamis & Roche (1994), which uses height, weight, chronological age and the average height of both parents; subsequently the percentage of adult height achieved at the time of observation was calculated for all subjects.

**Physical fitness.** A standardized 10-minute warm-up guided by the club's physical trainer consisted of joint mobility, jogging, skipping and vertical jumps. All participants were familiarized with jumping techniques prior to the test as part of their daily training. Each player performed two jumps of each SJ, CMJ, and ABK, with the instruction to jump as high as possible, if a player manifested more than 1 cm in height between jumps of the same style, another jump was performed. Between tests there was a passive rest of two minutes. The highest jump of each technique was analyzed.

**Squat jump (SJ).** The players were instructed to start the jump in the position of the 90° knee flexion with the feet a shoulder-width apart and with their hands on their hips. They were asked to jump for maximum height and maintain their hands on their hips, in case of any mistake, the jump was repeated.

**Countermovement jump (CMJ).** The CMJ starting position was a standing position with a straight torso and knees fully extended with the feet shoulder-width apart. The players were asked to keep their hands on their hips throughout the whole jump. They were instructed to perform a quick downward movement (approximately 90° of knee flexion), and afterward a fast-upward movement to jump as high as possible (also they were asked to keep their hands in their hips, to maintain their body vertical throughout the jump, and to land with their knees fully extended.

**Abalakov jump (ABK).** The technique is like CMJ with the exception of arm movement. The players were instructed to swing back with their arms during the downward movement and forward during the upward movement. They were instructed to keep their body vertical throughout the jump, and to land with their knees fully extended. All the jumps were recorded with an iPhone X (v.13, Apple Inc., Cupertino, CA, USA) through the My Jump 2 app, this app has been validity in youth population by.

**Sprint in a 40 m distance.** First, players performed a 8 min warm-up which included light running and dynamic stretching, followed by several maximal sprints over 20 m. The sprint was evaluated in 40 m distance carried out on a soccer field, additional three gates were used to evaluate the split time at 10 m, 20 m, and 30 m, which was instrumented with timing gates (Witty - Microgate; Bolzano, Italy), it has an accuracy of 0.001 s. The players were instructed to achieve the shortest time possible in the 40 m sprint. The test started from a standing position, 0.5 m behind the starting line, to ensure accurate registration of the first cut of the timing gate. Each player two maximal attempts performed, with a minimum recovery time of 3 minutes. For the analysis, the attempt with the best record was used.

**The 30-15 Intermittent Fitness Test (IFT).** The test was carried out on a soccer field and consisted of running for 30-second periods in out-and-back races with 15 seconds of passive recovery. Players ran a distance of 40 m, with a line in the center (at 20 m). The initial speed of the first period was 8 km/h, and subsequently, the speed increased by 0.5 km/h for each period. The players ran back and forth between the two lines located 40 m apart at a pace guided by a sound cue. At each sound, the players touched the corresponding line with their foot. During the 15-second recovery period, the players walked forward in the direction of the nearest line, where they also started the next period of the test. The players completed as many stages as possible, and the test ended when the players could no longer maintain the required running speed or when they were unable to reach the corresponding 3 m zone in time with the beep signal three consecutive times. The recorded score was the speed in the last stage of the participants, known as the intermittent speed (IFT).

**Statistical Analysis.** A normality analysis was performed using the Kolmogorov-Smirnov test. All numerical variables were presented as mean and standard deviation. Percentile tables (3rd, 10th, 25th, 50th, 75th, 90th, and 97th centiles) were developed for the performance tests as a function of maturity offset by the LMS method (Cole, 1989), using Chart Maker Pro version 2.5 software. The LMS method uses three parameters: L (Lambda) or transformation power, M (Mu) or mean, and S (sigma) or coefficient of variation. The degrees of freedom used for fitting the percentile curves were one for L, three for M, and one for S. ANOVA with post-hoc Bonferroni test was used to compare fitness tests between somatic maturation categories (Pre, Circa and Post PHV).

Pearson's correlation coefficient was used to establish the relationship between somatic maturation variables (MO-Moore-II, APHV-Moore-II, MO-Mirwald, APHV-Mirwald, and Percent adult height) and total muscle mass with physical performance tests. Additionally, a general linear model was conducted to determine which variables best explained the performance tests. MO-Moore-II, APHV-Moore-II, MO-

Mirwald, APHV-Mirwald, Percent adult height, total muscle mass, chronological age, height, skinfolds, humeral and femoral diameters, leg length, training frequency, training volume, sport age, injury history, and playing position were used as explanatory variables. All tests were performed with a confidence level of 95 %.

**RESULTS**

Post-PHV soccer players showed better performance in most of the tests compared to Pre-PHV (p<0.001) and Circa-PHV (p<0.001) players. In turn, Circa-PHV soccer players presented better performance than Pre-PHV players (Table I).

Table I. Mean and standard deviation of physical performance by maturity offset in male soccer players (MO-Moore-II).

| Variable | Pre PHV (n35) | | | Circa-PHV (n=28) | | | Post PHV (n=58) | | | P value |
|---|---|---|---|---|---|---|---|---|---|---|
| | Media | ± | DE | Media | ± | DE | Media | ± | DE | |
| SJ (cm) | 23.1 | ± | 4.3[ab] | 30.4 | ± | 4.9[ac] | 34.7 | ± | 5.0[bc] | <0.001 |
| CMJ (cm) | 23.7 | ± | 4.1[ab] | 32.5 | ± | 4.1[ac] | 36.3 | ± | 4.8[bc] | <0.001 |
| ABK (cm) | 27.5 | ± | 4.6[ab] | 37.3 | ± | 5.1[ac] | 42.2 | ± | 5.6[bc] | <0.001 |
| t0-10M (s) | 2.2 | ± | 0.3[ab] | 2.0 | ± | 0.2[a] | 2.0 | ± | 0.4[b] | 0.001 |
| t10-20M (s) | 1.6 | ± | 0.1[ab] | 1.3 | ± | 0.1[a] | 1.3 | ± | 0.1[b] | <0.001 |
| t20-30M (s) | 1.5 | ± | 0.1[ab] | 1.3 | ± | 0.1[a] | 1.3 | ± | 0.1[b] | <0.001 |
| t30-40M (s) | 1.5 | ± | 0.1 | 1.3 | ± | 0.1 | 1.4 | ± | 1.3 | 0.526 |
| Sprint in a 40 m distance (s) | 6.8 | ± | 0.4[ab] | 5.9 | ± | 0.4[ac] | 5.7 | ± | 0.4[bc] | <0.001 |
| 30-15 IFT (km/hr) | 16.1 | ± | 1.1[ab] | 18.2 | ± | 1.3[ac] | 19.1 | ± | 1.2[bc] | <0.001 |

SJ= Squat Jump; CMJ= Countermovement jump; ABK= Abalakov Jump; IFT= Intermittent Fitness Test; MO= Maturity Offset. ap-value <0.05 between Pre PHV and Circa PHV soccer players. bp-value <0.05 between Pre PHV and Post PHV soccer players. cp-value <0.05 between Circa PHV and Post PHV soccer players

In the smoothed percentile values of the physical performances test based on somatic maturation, adjusted by the LMS method, it be observed that as individuals progress towards PHV (-2 to 2 years from PHV), there is an improvement in performance across the tests: in the SJ, CMJ, and ABK tests, participants achieve greater jump distances; in the 40-meter sprint, the execution time decreases; and in the 30-15-IFT, the speed reached increases significantly (p<0.005). The coefficient of variation (S value) ranged from 6 % to 15 %. Respect to the L parameter, the highest values were for the 30-15-IFT (value of 2.4) (Table II).

Table II. Percentile values of different physical performance tests as a function of maturity offset in professional male soccer players.

| Maturity offset | L | M | S | 5 | 10 | 25 | 50 | 75 | 90 | 95 |
|---|---|---|---|---|---|---|---|---|---|---|
| SJ (cm) | | | | | | | | | | |
| -2 | 1.6 | 22.1 | 0.2 | 16.1 | 17.6 | 19.8 | 22.1 | 24.3 | 26.2 | 27.3 |
| -1 | 1.6 | 26.0 | 0.2 | 18.9 | 20.6 | 23.2 | 26.0 | 28.6 | 30.8 | 32.1 |
| 0 | 1.6 | 30.0 | 0.2 | 21.8 | 23.8 | 26.8 | 30.0 | 33.0 | 35.5 | 37.0 |
| 1 | 1.6 | 33.4 | 0.2 | 24.3 | 26.5 | 29.9 | 33.4 | 36.7 | 39.6 | 41.3 |
| 2 | 1.6 | 36.5 | 0.2 | 26.6 | 29.0 | 32.7 | 36.5 | 40.2 | 43.3 | 45.1 |
| CMJ (cm) | | | | | | | | | | |
| -2 | 1.4 | 23.2 | 0.1 | 17.3 | 18.6 | 20.8 | 23.2 | 25.4 | 27.3 | 28.5 |
| -1 | 1.4 | 27.0 | 0.1 | 20.2 | 21.8 | 24.3 | 27.0 | 29.7 | 31.9 | 33.2 |
| 0 | 1.4 | 31.4 | 0.1 | 23.4 | 25.3 | 28.2 | 31.4 | 34.4 | 37.0 | 38.6 |
| 1 | 1.4 | 35.0 | 0.1 | 26.1 | 28.2 | 31.5 | 35.0 | 38.4 | 41.3 | 43.0 |
| 2 | 1.4 | 38.0 | 0.1 | 28.3 | 30.6 | 34.2 | 38.0 | 41.6 | 44.8 | 46.7 |
| ABK (cm) | | | | | | | | | | |
| -2 | 1.1 | 26.4 | 0.1 | 20.0 | 21.4 | 23.8 | 26.4 | 28.9 | 31.2 | 32.6 |
| -1 | 1.1 | 31.1 | 0.1 | 23.5 | 25.2 | 28.0 | 31.1 | 34.1 | 36.8 | 38.4 |
| 0 | 1.1 | 36.2 | 0.1 | 27.4 | 29.4 | 32.6 | 36.2 | 39.7 | 42.9 | 44.7 |
| 1 | 1.1 | 40.7 | 0.1 | 30.8 | 33.0 | 36.6 | 40.7 | 44.6 | 48.1 | 50.2 |
| 2 | 1.1 | 44.2 | 0.1 | 33.4 | 35.8 | 39.8 | 44.2 | 48.5 | 52.3 | 54.6 |
| Sprint in a 40 m distance (s) | | | | | | | | | | |
| -2 | -1.2 | 6.9 | 0.1 | 6.3 | 6.4 | 6.6 | 6.9 | 7.2 | 7.5 | 7.7 |
| -1 | -1.2 | 6.5 | 0.1 | 5.9 | 6.0 | 6.2 | 6.5 | 6.7 | 7.0 | 7.2 |
| 0 | -1.2 | 6.0 | 0.1 | 5.5 | 5.6 | 5.8 | 6.0 | 6.3 | 6.5 | 6.7 |
| 1 | -1.2 | 5.7 | 0.1 | 5.2 | 5.3 | 5.5 | 5.7 | 6.0 | 6.2 | 6.3 |
| 2 | -1.2 | 5.5 | 0.1 | 5.0 | 5.1 | 5.3 | 5.5 | 5.7 | 6.0 | 6.1 |
| 30-15 IFT (km/h) | | | | | | | | | | |
| -2 | 2.4 | 15.8 | 0.1 | 14.0 | 14.4 | 15.1 | 15.8 | 16.5 | 17.1 | 17.4 |
| -1 | 2.4 | 17.0 | 0.1 | 15.0 | 15.5 | 16.2 | 17.0 | 17.7 | 18.3 | 18.7 |
| 0 | 2.4 | 18.1 | 0.1 | 16.0 | 16.5 | 17.3 | 18.1 | 18.9 | 19.5 | 19.9 |
| 1 | 2.4 | 19.0 | 0.1 | 16.8 | 17.3 | 18.1 | 19.0 | 19.8 | 20.4 | 20.8 |
| 2 | 2.4 | 19.4 | 0.1 | 17.2 | 17.7 | 18.5 | 19.4 | 20.2 | 21.0 | 21.4 |

SJ= Squat Jump; CMJ= Countermovement jump; ABK= Abalakov Jump; IFT= Intermittent Fitness Test. Maturity offset was estimated according to Moore-II method (2015).

In addition, MO- Moore-II method correlated slightly better than that MO-Mirwald method with the physical performance tests, obtaining correlation coefficients ≥0.7 (p<0.001); as well as the percentage of adult height which also showed good correlation with the physical performance tests (r≥0.7, p<0.001). MO and percent of adult height were directly associated with SJ, CMJ, ABK, and 30-15-IFT (p<0.001) and inversely with 40-meter sprint running time (p<0.001) (Table III).

The general linear model established for the SJ test, the explanatory variables were MO-Moore-II (p<0.001) and training frequency (p=0.042); for the CMJ test, were MO-Moore-II (p<0.001), playing position (p=0.017), and injuries history (p=0.034); for the ABK test, were the percentage of adult height (p=0.001) and training frequency (p=0.033); for the execution of a sprint in the first 10 meters, was only the percentage of adult stature (p=0.004); and for the 30-15 IFT, were playing position (p<0.001), MO-Moore-II (p=0.007), and training volume (p=0.020). Table IV presents a summary of the models.

Table III. Pearson correlation coefficient between somatic maturation and muscle mass variables with physical performance variables.

| Variable | SJ (cm) | | CMJ (cm) | | ABK (cm) | | t0-10M (s) | | t10-20M (s) | | t20-30M (s) | | t30-40M (seg) | | Sprint in a 40 m distance (s) | | 30-15 IFT (km/hr) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | r | p | r | p | r | p | r | p | r | p | r | p | r | p | r | p | r | p |
| MO-Mirwald (years) | 0.71 | <0.001 | 0.72 | <0.001 | 0.71 | <0.001 | -0.18 | 0.058 | -0.65 | <0.001 | -0.62 | <0.001 | -0.01 | 0.900 | -0.64 | <0.001 | 0.63 | <0.001 |
| APHV Mirwald (years) | 0.14 | 0.135 | 0.23 | 0.014 | 0.24 | 0.012 | -0.20 | 0.039 | -0.11 | 0.266 | -0.05 | 0.625 | 0.07 | 0.466 | -0.22 | 0.021 | 0.32 | 0.001 |
| MO-Moore-II (years) | 0.73 | <0.001 | 0.75 | <0.001 | 0.76 | <0.001 | -0.24 | 0.008 | -0.70 | <0.001 | -0.64 | <0.001 | -0.01 | 0.946 | -0.70 | <0.001 | 0.68 | <0.001 |
| APHV Moore-II (years) | 0.30 | 0.001 | 0.36 | <0.001 | 0.35 | <0.001 | -0.16 | 0.075 | -0.24 | 0.008 | -0.19 | 0.033 | 0.01 | 0.897 | -0.32 | <0.001 | 0.43 | <0.001 |
| Percentage of Adult Height (%) | 0.72 | <0.001 | 0.73 | <0.001 | 0.75 | <0.001 | -0.29 | 0.002 | -0.80 | <0.001 | -0.61 | <0.001 | -.820** | <0.001 | -0.73 | <0.001 | 0.68 | <0.001 |
| Total Muscle Mass (kg) | 0.58 | <0.001 | 0.59 | <0.001 | 0.61 | <0.001 | -0.32 | 0.000 | -0.51 | <0.001 | -0.46 | <0.001 | 0.05 | 0.571 | -0.60 | <0.001 | 0.48 | <0.001 |

PHV= Peak Height Velocity; APHV= Age at the Peak Height Velocity; SJ= Squat Jump; CMJ= Countermovement jump; ABK= Abalakov Jump; IFT= Intermittent Fitness Test.

Table IV. Analysis of variance of different physical performance tests and explanatory variables such as maturation, anthropometry, body composition and training in male soccer players.

| Source of variation | Sum of squares type III | df | Mean square | F | p value |
|---|---|---|---|---|---|
| **SJ (cm) $R^2$= 0.574** | | | | | |
| Corrected model | 3266.7 | 4 | 816.7 | 39.1 | <0.001 |
| Intersection | 10803.2 | 1 | 10803.2 | 517.9 | <0.001 |
| MO-Moore-II (years) | 287.0 | 1 | 287.0 | 13.8 | <0.001 |
| Training frequency (days/week) | 176.0 | 3 | 58.7 | 2.8 | 0.042 |
| Error | 2419.9 | 116 | 20.9 | | |
| Total | 117428.2 | 121 | | | |
| Total corrected | 5686.6 | 120 | | | |
| **CMJ (cm) $R^2$= 0.623** | | | | | |
| Corrected model | 3654.2 | 6 | 609.0 | 31.6 | <0.001 |
| Intersection | 75188.2 | 1 | 75188.2 | 3905.8 | <0.001 |
| Position | 241.1 | 4 | 60.3 | 3.1 | 0.017 |
| Injury history | 91.0 | 1 | 91.0 | 4.7 | 0.032 |
| MO-Moore-II (years) | 2526.9 | 1 | 2526.9 | 131.3 | <0.001 |
| Error | 2213.8 | 115 | 19.3 | | |
| Total | 129410.1 | 122 | | | |
| Total corrected | 5868.0 | 121 | | | |
| **ABK(cm) $R^2$= 0.589** | | | | | |
| Corrected model | 4585.6 | 3 | 1528.5 | 53.4 | <0.001 |
| Intersection | 47.1 | 1 | 47.1 | 1.6 | 0.202 |
| PAS (%) | 333.4 | 1 | 333.4 | 11.7 | 0.001 |
| Training frequency (days/week) | 201.3 | 2 | 100.7 | 3.5 | 0.033 |
| Error | 3204.6 | 112 | 28.6 | | |
| Total | 165947.4 | 116 | | | |
| Total corrected | 7790.3 | 115 | | | |
| **t0-10M (s) $R^2$ = 0.117** | | | | | |
| Corrected model | 1.6 | 2 | 0.8 | 7.5 | 0.001 |
| Intersection | 1.8 | 1 | 1.8 | 16.6 | <0.001 |
| PAS (%) | 0.9 | 1 | 0.9 | 8.5 | 0.004 |
| MO-Moore-II (years) | 0.5 | 1 | 0.5 | 4.6 | 0.033 |
| Error | 12.1 | 113 | 0.107 | | |
| Total | 503.5 | 116 | | | |
| Total corrected | 13.7 | 115 | | | |
| **Sprint in a 40 m distance (s) $R^2$= 0.600** | | | | | |
| Corrected model | 29.9 | 3 | 10.0 | 58.6 | <0.001 |
| Intersection | 541.8 | 1 | 541.8 | 3185.5 | <0.001 |
| Training frequency (days/week) | 29.9 | 3 | 10.0 | 58.6 | <0.001 |
| Error | 19.9 | 117 | 0.2 | | |
| Total | 4530.3 | 121 | | | |
| Total corrected | 49.8 | 120 | | | |
| **30-15 IFT (km/h) $R^2$= 0.648** | | | | | |
| Corrected model | 233.7 | 6 | 38.9 | 33.5 | <0.001 |
| Intersection | 351.0 | 1 | 351.0 | 301.7 | <0.001 |
| Training volume | 6.5 | 1 | 6.5 | 5.6 | 0.020 |
| MO-Moore-II (years) | 8.7 | 1 | 8.7 | 7.5 | 0.007 |
| Position | 41.5 | 4 | 10.4 | 8.9 | <0.001 |
| Error | 126.8 | 109 | 1.2 | | |
| Total | 38233.0 | 116 | | | |
| Total corrected | 360.4 | 115 | | | |

MO= Maturity Offset; PAS= Percentage of Adult Height; SJ= Squat Jump; CMJ= Countermovement jump; ABK= Abalakov Jump; IFT= Intermittent Fitness Test.

## DISCUSSION

The present study is the first work carried out, to our knowledge, with a professional soccer club in Mexico that analyzes the relationship between somatic maturation and physical performance in male soccer players belonging to a professional soccer academy, observing how the PHV and the percentage of adult height presented a better association with performance than the chronological age; in addition to proposing percentile values for different physical tests as a function of PHV.

In the literature, there is evidence discussing the relationship between performance and somatic maturation finding that Post-PHV adolescents present better performance compared to Pre-PHV, specifically in Change of direction (CoD), external visual imagery and higher anaerobic power (Nobari *et al*., 2023), similar results to those found in our study.

However, while soccer players who are Post-PHV appear to exhibit better physical performance, the optimal "windows of opportunity" for training adaptations may favor those who are PRE-PHV or Circa-PHV. Philippaerts *et al*. (2006), observed greater longitudinal changes in explosive strength, speed, and agility in Circa-PHV soccer players compared to Post-PHV players. Similarly, it has been observed that both Circa-PHV and Post-PHV soccer players show a better adaptive response to training loads than Pre-PHV players (Moran *et al*., 2017). On the other hand, research has shown that Pre-PHV soccer players may demonstrate better aerobic running economy and experience a lower injury rate and load compared to Circa-PHV and Post-PHV soccer players (Mandorino *et al*., 2022). In terms of tactics and effectiveness, it has been observed that Post-PHV players exhibit better execution effectiveness in penetration compared to Pre-PHV players; however, the latter demonstrate greater tactical variability (Reis & Almeida, 2020).

Another aspect to consider is that during adolescence, the development of movement quality is not linear and tends to stagnate during the PHV. This might be due to the accelerated physical growth experienced during this stage of maturation, which is not accompanied by a corresponding advancement in sensorimotor function. This delay can potentially interrupt previously established motor patterns. Therefore, considering the PHV and other indicators of biological maturation could aid in the development of strategies to enhance the growth of young soccer players and reduce the risk of injuries (Towlson *et al*., 2021).

An important finding in the current study was that PHV and the percentage of adult height exhibited stronger associations with physical performance indicators compared to chronological age. The latter remains crucial for grouping adolescents and prescribing training loads. In the existing literature, a study of soccer players within professional academies in the United Kingdom observed that biological maturation status has a more significant correlation with sprint performance in comparison to relative age (Radnor *et al*., 2021).

Based on the above, a study conducted by Romann *et al*. (2020), revealed that the classification of 12- to 13-year-old soccer players based on their somatic maturation, known as Bio-Banding, yielded positive effects on crucial indicators of physiological and technical-tactical performance within elite youth soccer, such as an increase in the number of duels and set pieces, a decrease in the average time of ball possession per action, lower rate of successful passes and a shorter differences between players in the execution of jogging, running and high-speed running (sprints) when they were classified based on Bio-banding compared to when they were classified based on their chronological age. Myburgh *et al*. (2016) suggest using this classification system based on biological maturity (Bioo-banding) to enhance the development of physical, tactical and technical skills by grouping athletes in similar physical and biological conditions. On the other hand, the combination of birth date and biological maturation has been identified as potential indicators for talent selection.

Furthermore, in the present study we generated percentile values for different physical performance tests widely used in soccer according to the state of somatic maturation (maturity offset). These references data provide a useful tool to evaluate and compare the physical performance of young soccer players, taking into account their level of biological maturation. Likewise, they can guide coaches and sports professionals in decision-making processes when evaluating the physical performance of young soccer players. Commonly percentile values are generated as a function of chronological age; however, it has been shown that individuals of the same chronological age may have different biological maturation (Lloyd *et al*., 2014), in addition to the fact that growth and biological maturation do not present a linear growth pattern and there is inter-subject variation in the tempo, timing, and magnitude of maturation (Cameron & Schell, 2021).

In conclusion, the current study revealed that the percentage of adult height and MO-Moore-II provided better explanations for performance tests compared to chronological age commonly used for classifying soccer players. Furthermore, these indicators exhibited stronger associations with performance than training volume, sport age, the number of previous injuries, or anthropometric characteristics such as height, bone diameters, or body composition.

**Limitations and recommendations.** One of the limitations of the present study was to have a sample focused only on a professional soccer club in Mexico; however, it serves as a reference point in future research for the comparison of physical performance in relation to somatic maturation. In addition, it would be important to develop more studies that also analyze specific soccer skills such as changes of direction with and without the ball, dribbling, successful passes, recovered balls, etc., in relation to the state of biological maturation.

**CARRANZA-GARCÍA, L. E.; CERVANTES-HERNÁNDEZ, N.; DOMÍNGUEZ-SOSA, M.; ALANÍS-FLORES, M.; LÓPEZ-GARCÍA, R.; VASQUEZ-BONILLA, A. & FLORES, L. A.** Madurez somática y rendimiento físico en jugadores juveniles masculinos de una academia de fútbol profesional. *Int. J. Morphol., 42(2)*:429-436, 2024.

**RESUMEN:** El objetivo fue analizar la relación entre la maduración somática y el rendimiento físico en futbolistas juveniles masculinos pertenecientes a una academia profesional mexicana. Métodos. En 121 futbolistas masculinos de 11 a 16 años de una academia profesional se estimó la velocidad máxima en altura (VPH), porcentaje de altura adulta (PAS), capacidad de salto, sprint, velocidad intermitente y masa muscular. Se realizó ANOVA para comparar variables de desempeño entre categorías somáticas de madurez y se calcularon percentiles en función de la compensación de madurez utilizando el método LMS. Además, se empleó un modelo lineal general para determinar las variables explicativas del desempeño. Los jugadores de fútbol post-PHV demostraron un rendimiento físico superior en varias pruebas en comparación con los jugadores Pre-PHV ($p<0{,}001$) y Circa-PHV ($p<0{,}001$). Los valores percentiles suavizados de las pruebas de rendimiento, basados en la maduración somática, indicaron una mejora progresiva del rendimiento a medida que los individuos se acercaban al PHV (-2 a 2 años desde el PHV) ($p<0{,}005$). PHV se asoció con la capacidad de salto ($p<0{,}001$) y velocidad intermitente ($p=0{,}007$) mientras que PAS se asoció con el tiempo en sprint ($p=0{,}0004$). En conclusión PHV y PEA explicaron un mejor rendimiento que la edad cronológica, las características de composición corporal, las lesiones o los factores de entrenamiento.

**PALABRAS CLAVE: Velocidad máxima de altura; Brote de crecimiento; Madurez somática; Jugadores de futbol; Aptitud física.**

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Corresponding author:
Luis Alberto Flores Olivares
Circuito Universitario Campus 2 Fracc.
Campo Bello Chihuahua
Chihuahua, C.P. 31124
MÉXICO

E-mail: lolivares@uach.mx