



Comparison of physical fitness and body composition by age categories in young professional football players in Chile

Comparación de la condición física y composición corporal por categorías de edad en futbolistas jóvenes profesionales en Chile

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Abstract

Introduction: physical and morphological development in youth football depends on age, maturation, and training loads. understanding these variations is key to planning the developmental process.

Objective: to compare body composition and physical condition of young professional football players in Chile across different age categories.

Method: 223 players from a professional club participated. body composition was assessed through fat mass, muscle mass, and the sum of six skinfolds. physical performance included countermovement jump, 10- and 30-meter sprints, change of direction test, one-repetition maximum squat, yo-yo intermittent recovery test, and kicking ability. a univariate anova was applied to compare variables between categories.

Results: significant differences were found in all variables ($p < 0.05$; $\eta^2 > 0.14$). post hoc analyses showed that older players had greater muscle mass, lower fat mass, and superior performance in strength and endurance tests, while younger categories presented lower values in these indicators.

Discussion: findings confirm that maturation and training promote progressive improvements in physical and morphological capacities. variability across categories highlights the importance of considering both age and biological maturation.

Conclusions: a clear physical and morphological progression was observed in youth footballers according to category, influenced by maturation and training. integrating biological factors into planning is essential to optimize performance and prevent injuries.

Keywords

Physical qualities, biotype, maturation, performance, youth.

Resumen

Introducción: El desarrollo físico y morfológico en el fútbol juvenil depende de la edad, la maduración y las cargas de entrenamiento. comprender estas variaciones es clave para planificar el proceso formativo.

Objetivo: Comparar la composición corporal y la condición física de jóvenes futbolistas profesionales en Chile en diferentes categorías de edad.

Método: 223 jugadores de un club profesional. la composición corporal se evaluó mediante masa grasa, masa muscular y suma de seis pliegues cutáneos. El rendimiento físico incluyó salto de contramovimiento, sprints de 10 y 30 metros, prueba de cambio de dirección, sentadilla máxima de una repetición, test yo-yo de recuperación intermitente y capacidad de patada. Se aplicó un ANOVA univariante para comparar las variables entre categorías.

Resultados: Diferencias significativas en todas las variables ($p < 0,05$; $\eta^2 > 0,14$). Los análisis post hoc mostraron que los jugadores de mayor edad presentaron más masa muscular, menor masa grasa y mejor desempeño en pruebas de fuerza y resistencia, mientras que las categorías menores evidenciaron valores más bajos en estos indicadores.

Discusión: Los hallazgos confirman que la maduración y el entrenamiento favorecen mejoras progresivas en capacidades físicas y morfológicas. la variabilidad entre categorías subraya la importancia de considerar edad y maduración biológica.

Conclusiones: Se confirma una progresión física y morfológica en futbolistas juveniles según la categoría, influida por maduración y entrenamiento. se resalta la necesidad de integrar factores biológicos en la planificación para optimizar rendimiento y prevenir lesiones.

Palabras clave

Cualidades físicas, biotipo, maduración, rendimiento, fútbol formativo.

Introduction

In youth football, the development of body composition and physical qualities are key variables for optimizing performance and enhancing talent in the short, medium, and long term (Towlson & Cumming, 2022). Players' adaptation to the physical demands of training can vary significantly depending on age, training background, biological maturity and the specific characteristics of their position on the field (Leão et al., 2022). Anthropometric measurements, such as the percentage of fat mass, muscle mass, and sum of six skinfolds, along with physical performance tests, including speed, change of direction, jump, throw, strength and endurance, are fundamental tools to understand the abilities and limitations of the players across different age categories (Pérez-Contreras et al., 2022). These evaluations provide a comprehensive view of players' physical profile, enabling specific and contextualized planning for their development (Castagna, Manzi, Impellizzeri, Weston, & Barbero Alvarez, 2010).

From U11 to U21 levels in youth football categories, physical and anthropometric assessments are essential for identifying areas requiring improvement and for strengthening the physical attributes that are critical for competitive performance (Kobal et al., 2016). The literature indicates that the constant monitoring of physical variables, in conjunction with body composition analysis, helps to plan more specific training programs adapted to the needs of each age group (Leão et al., 2022). Furthermore, such assessments are instrumental in determining the biological maturity of the players, thereby enabling the adjustment of training sessions to align with individual capabilities and the demands of their tactical role (Paul & Nassis, 2015).

Despite the recognized importance of these measurements in the training of football players, a limited body of research systematically compares body composition and physical qualities across various categories in the Latino and Chilean population (Pérez-Contreras et al., 2021, 2022). Furthermore, the lack of standardized protocols complicates reliable comparisons between teams, categories, and training contexts (Paul & Nassis, 2015). This lack of detailed research not only hinders the identification of patterns in physical development among young players, but also restricts the ability of coaches and athletic trainers to implement precise interventions that appropriately align with age-specific categories (Kobal et al., 2016).

Therefore, this study aims to compare the body composition and physical performance of football players across formative categories, ranging from U11 to U21. It is hypothesized that with increasing age and physical maturity, players will exhibit improvements in most of the variables evaluated, particularly in those aspects related to muscle mass, strength, speed, and endurance. This research seeks to generate relevant data on the evolution of anthropometric and physical parameters in youth football categories, thereby offering valuable tools to optimise training, planning, and the comprehensive development of young footballers.

Method

This research is cross-sectional, with a quantitative approach, of a descriptive and comparative nature.

Participants

A non-random convenience sampling was used, with the participation of 223 football players belonging to seven training categories of a professional football club in Chile of the first division. The country's football federation defined these categories according to the year of birth: U11 (n = 33), U12 (n = 25), U13 (n = 36), U14 (n = 36), U15 (n = 21), U16 (n = 24), U18 (n = 28) and U21 (n = 20). The evaluations were carried out in December 2024 at the end of the season. The evaluation protocols were designed so that they did not alter the usual training practices, nor introduce motor actions different from those commonly performed in the team dynamics.

Prior to data collection, all players were duly informed about the procedures, objectives, risks, and benefits of the study and were guaranteed the freedom to withdraw at any time. Players over 18 years of age signed an informed consent, while for minors the assent signed by their parents or legal guardians was obtained. The study was carried out following the ethical regulations of the club, the Chilean football

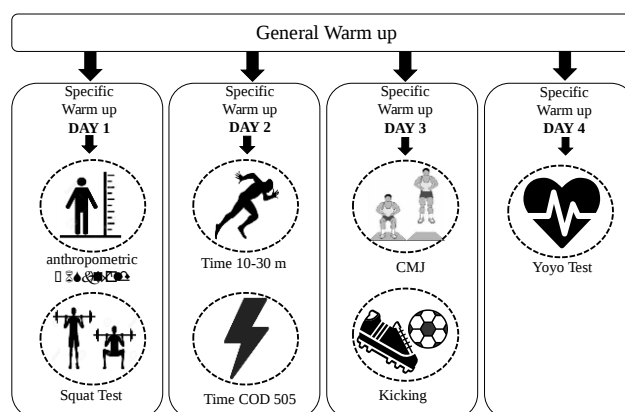


federation and the principles established in the Declaration of Helsinki on research on human beings (World Medical Association, 2013).

Procedure

The body composition and physical condition evaluations were carried out during the morning, under controlled environmental conditions: temperature of 15°C and relative humidity of approximately 75%. To minimise the effects of fatigue, participants were asked to avoid strenuous exercise for 24 hours prior to the tests. Before the evaluation, each category underwent a general warm-up protocol led by their physical trainer that included a general phase, composed of easy running, multidirectional movements and dynamic stretching, followed by a specific phase, in which specific exercises were performed for each event. All the players were familiar with the evaluations, as they are part of the battery of physical and anthropometric tests that the club carries out annually in its divisions in formation (figure 1) (Pérez-Contreras et al., 2022; Villaseca-Vicuña et al., 2021). Each player was encouraged to run each test with the maximum effort possible. All physical evaluations were carried out on artificial turf, and the players wore shoes with studs suitable for this type of surface. In categories U11 and U12, aerobic intermittent performance and specific strength actions were not assessed due to maturational aspects. In these categories, only basic movement patterns such as jumping and running were evaluated, which is indicated in the tables with the symbol (Lloyd & Oliver, 2012).

Figure 1. Body composition and physical condition assessments



Instrument and variables

Body Composition

The weight and height of each player were measured using a scale with a height gauge (Seca 700®, Hamburg, Germany). In addition, the sum of six skinfolds (tricipital, subscapular, supraspinal, abdominal, medial thigh and calf maximum) was recorded, using these data to estimate the percentage of fat (% Fat Mass) and the percentage of muscle (% Muscle Mass). All procedures were performed in accordance with the standards of the International Society for the Advancement of Kinanthropometry (ISAK) and were performed by a certified ISAK III specialist, belonging to the football club's staff. Skinfold measurements were performed with a high-precision (0.2 mm) thin-guide caliper (Rosscraft®, British Columbia, Canada). Prior to data collection, inter-rater reliability was assessed on a pilot sample, obtaining a technical error of measurement (TEM) within the acceptable range established by ISAK (<5% for skinfolds).

Squat Test

This test has been validated to assess lower limb muscle strength levels in footballers (González-Badillo et al., 2017; González-Badillo et al., 2010; Martínez-Cava et al., 2019; Pareja-Blanco et al., 2017). Before the measurement, each player performed a specific warm-up of 3 sets and 3 repetitions with a load of 20 kg. In the evaluation, each player performed 1 set of 3 repetitions, with each load of: 20, 30, 40, 50, 60, 70 and 80 kg respectively, with a recovery of 3 minutes between sets. The concentric phase of the

exercise was required to be executed at the maximum possible speed. No participant reached the decision in any series. Two variables were recorded: a) relative strength (RS) obtained from the ratio between 1RM/Body Weight; b) estimation of the 1RM determined from the mean propulsive velocity (MPV) of the last load of the test (40 kg category U13-14; 60 kg category U15-16; 80 kg category U18-21), calculated from the equation proposed by (Pareja-Blanco et al., 2020) the U13-14 category; The aforementioned variables were determined using the linear encoder (ADR encoder®, Toledo, Spain). Equation to calculate the 1RM in the squat from the MPV at the last load:

$$\%1RM = (-42.196 MPV^2 - 31.018 MPV + 112.937)$$

Linear sprint time in 10 (T10) and 30 meters (T30)

This test is commonly used to assess maximum running speed in footballers (Pérez-Contreras et al., 2021; Villaseca-Vicuña et al., 2024). Prior to the evaluation, the players performed a specific warm-up, which included five progressive 30-meter runs. Each player made three attempts of 30 meters, with three minutes of recovery between each one. The starting position was standing, with the forward foot placed just behind a line located 0.5 meters from the first photoelectric cell (Witty gate, Microgate®, Bolzano, Italy), to avoid premature interruptions of the light beam with the head or arms. Photoelectric cells were used at the starting points, 10 meters and 30 meters, recording the time in two segments, at the distance from 0 to 10 meters (T10) and time recorded at the distance from 0 to 30 meters (T30). For the analysis, the best time of the three attempts was considered.

Change of direction 505 modified (COD)

Prior to the test, a standardized warm-up was carried out by the physical trainer, which consisted of 6 accelerations and a 5-meter brake. The protocols for this test have already been documented in the literature (Pérez-Contreras et al., 2024). With a single-beam photocell (Witty gate, Microgate®, Bolzano, Italy), placed at the exit at a vertical height of 1 meter, players positioned with one foot 0.5 meters behind the exit gate, had to exit and step on the mark (white tape) 5 meters to return. A mark was left six feet from the start and a researcher verbally encouraged players not to stop until they crossed the mark. Four attempts were made and 2 changes of direction were indicated for each profile, where the result was obtained by averaging both attempts. When a player did not reach the indicated mark of 5 meters, the attempt was considered null and repeated until two valid attempts were reached. Players had 2 minutes of rest between attempts.

Countermovement Jump (CMJ)

This test is usually done to measure the power of the lower limbs of football players (Kobal et al., 2016a; Romero-Caballero et al., 2021). Before performing the test, each player performed a specific 5-jump warm-up to a jump box, the target surface of which was 40 cm from the ground. In the test, participants made 3 attempts. The starting position is upright with the hands on the waist throughout the test to eliminate any influence of arm swing. From this position the participant quickly bends the knees to approximately 90° and then immediately pushes off to jump vertically as high as possible, landing on both feet at the same time and with the knees extended (Kammoun et al., 2020). If the evaluator observed an execution error, the jump was invalidated and the execution was repeated. This test was evaluated using an infrared platform (Optojump Microgate® contact platform, Bolzano, Italy), with 3 minutes of rest between repetitions. The jump height (cm) was recorded and the best result was selected.

Kicking

This physical-technical test assesses the speed of the kicking, a parameter widely analysed in footballers (Bouguezzi et al., 2020). Before the measurement, each player performed a specific warm-up, which consisted of 10 long passes with the instep. During the evaluation, the players executed three attempts with the dominant leg, using the total instep and with three minutes of recovery between each attempt. For the statistical analysis, the highest recorded velocity was considered. The players were instructed to kick the ball with the maximum possible speed, directing it towards a target of 1 meter in diameter, located in the center of the goal (Rada et al., 2019). The ball remained static 8 meters from the goal (Molten Vantaggio 5000® ANFP 2023 Professional Ball, Hiroshima, Japan), allowing an approach run of 1 meter. A speed measuring radar (Supido Multideporte®, Blackpool, United Kingdom). Located 1 meter

behind the gantry, according to the specific instructions of the radar (Díez-Fernández et al., 2022). This device has demonstrated high reliability and concurrent validity for measuring ball speed during soccer kicking, as reported by Díez-Fernández et al. (2022), supporting its suitability for use in professional football contexts. If the execution did not meet the established criteria (e.g., contact with an inappropriate area of the foot or lack of precision in the direction of the shot), the attempt was discarded and repeated.

Yo-Yo Intermittent Recovery Test Level I (YYIR1)

This test is used to assess the intermittent endurance capacity in footballers (Pérez-Contreras et al., 2022). Before the measurement, each player performed a specific warm-up that consisted of 10 repetitions of submaximal runs in 20 m with changes of direction. The players made one attempt at the test, following the test protocol (Bangsbo et al., 2008). For the statistical analysis, the meters traveled were recorded.

Data analysis

For the descriptive analysis, the mean and standard deviation (mean $\pm$ SD) were calculated. The ICC and CV were obtained to determine the absolute and relative reliability of the variables measured more than twice. The Kolmogorov-Smirnov test was performed to determine if the variables followed a normal distribution. In addition, the homogeneity of the variances was checked with the Levene test. No additional assumption tests beyond normality and homogeneity of variance were conducted. A one-way analysis of variance was used to examine differences between categories. Post hoc analyses were performed using the Tukey or Games-Howell tests. For the magnitude of the differences between groups, the effect size (ET) was analyzed using η^2 , the ETs will be categorized as: trivial (< 0.01), small ($0.01 - 0.06$), medium ($0.07 - 0.14$) and large (> 0.14) (Cohen, 1992). Statistical significance was established at $p \leq 0.05$ and the confidence interval (CI) at 95% for all measures. For the analysis, the SPSS program (SPSS IBM,® version 22, New York, USA) was used.

Results

Table 1 presents the absolute (coefficient of variation, CV) and relative (intraclass correlation coefficient, ICC) reliability values for the variables measured on more than two occasions, stratified by age category. These metrics provide an assessment of the measurement consistency and variability across repeated trials within each group.

Table 1. Reliability of performance variables across age categories (U21–U11).

		U21	U18	U16	U15	U14	U13	U12	U11
Time to 10 meters (s)	CV	4.45%	2.73%	2.56%	3.48%	1.59%	2.21%	2.27%	2.66%
	ICC	0.751	0.773	0.722	0.756	0.818	0.827	0.698	0.711
Time to 30 meters (s)	CV	0.76%	1.20%	1.03%	0.85%	1.21%	1.80%	1.39%	3.62%
	ICC	0.907	0.721	0.796	0.909	0.701	0.855	0.830	0.784
COD 505 Right (s)	CV	2.08%	2.16%	3.06%	3.09%	5.27%	2.04%	2.51%	2.30%
	ICC	0.708	0.681	0.713	0.629	0.731	0.685	0.646	0.639
COD 505 Left (s)	CV	4.08%	2.37%	2.01%	2.69%	2.11%	1.83%	2.62%	2.18%
	ICC	0.688	0.799	0.589	0.666	0.792	0.770	0.651	0.794
Countermovement Jump (cm)	CV	3.05%	3.67%	3.84%	3.59%	3.64%	3.43%	3.88%	4.55%
	ICC	0.822	0.864	0.896	0.863	0.933	0.957	0.942	0.819
Kicking (km/h)	CV	2.32%	2.16%	2.61%	3.88%	3.23%	3.18%	4.16%	-
	ICC	0.689	0.735	0.777	0.637	0.743	0.700	0.740	-

COD: Change of Direction; CV: Coefficient of Variation; ICC: Intraclass Correlation Coefficient.

Table 2 shows the variables of body composition and anthropometry according to age category. Large differences were found in all the variables analyzed ($p < 0.05$ and $\eta^2 > 0.14$).

Table 2. Description of the body composition variables of each category according to age.

		U21 (n=20)	U18 (n=28)	U16 (n=24)	U15 (n=21)	U14 (n=36)	U13 (n=36)	U12 (n=25)	U11 (n=33)	p value	η^2
Body Weight (kg)	M	72.22	71.90	68.91	66.86	61.89	56.14	47.30	39.91	<0.001	0.690
	SD	8.01	7.74	7.08	5.48	7.66	8.58	7.27	6.72		
Height (cm)	M	175.79	178.43	177.75	168.38	170.85	166.03	156.76	146.65	<0.001	0.510
	SD	7.47	5.81	7.34	24.51	7.72	8.28	6.79	6.61		



Sum 6	M	39.74	42.47	48.43	54.40	44.57	51.44	53.38	53.32		
Skinfolds (mm)	SD	9.69	13.27	11.62	10.03	10.36	28.64	17.00	20.28	0.019	0.080
% Fat Mass	M	14.06	20.18	23.54	24.05	22.35	23.76	26.89	27.87		
	SD	3.51	2.35	2.67	2.45	2.79	3.58	3.01	3.77	<0.001	0.595
% Muscle Mass	M	51.18	50.37	46.92	47.10	47.23	44.88	41.39	40.74		
	SD	2.24	2.24	2.35	2.47	2.95	3.51	2.72	3.51	<0.001	0.590

Table 3 shows the variables of physical condition according to age category, Large differences were found in all the variables analyzed ($p < 0.05$ and $\eta^2 > 0.14$).

Table 3. Description of the physical condition variables of each category according to age

		U21 (n=20)	U18 (n=28)	U16 (n=24)	U15 (n=21)	U14 (n=36)	U13 (n=36)	U12 (n=25)	U11 (n=33)	p value	η^2
Time to 10 meters (s)	M	1.68	1.701	1.70	1.72	1.80	1.87	1.927	2.033	<0.001	0.626
	SD	0.07	0.08	0.04	0.06	0.11	0.12	0.094	0.100		
Time to 30 meters (s)	M	4.08	4.12	4.21	4.34	4.51	4.77	4.720	4.971	<0.001	0.693
	SD	0.14	0.12	0.11	0.15	0.22	0.32	0.208	0.179		
COD 505 Right (s)	M	2.52	2.51	2.57	2.52	2.58	2.69	2.871	2.934	<0.001	0.695
	SD	0.10	0.09	0.11	0.08	0.11	0.11	0.137	0.141		
COD 505 Left (s)	M	2.54	2.54	2.60	2.55	2.65	2.72	2.921	3.034	<0.001	0.660
	SD	0.09	0.08	0.09	0.09	0.13	0.13	0.150	0.150		
Countermovement Jump (cm)	M	43.00	41.26	39.12	38.82	34.02	29.97	28.059	25.050	<0.001	0.702
	SD	4.31	4.26	4.61	4.25	5.30	2.96	3.155	3.541		
Kicking (km/h)	M	108.83	106.92	103.56	104.62	93.66	90.03	82.000	-	<0.001	0.706
	SD	4.21	4.72	6.08	5.92	6.90	6.86	5.523	-		
1RM Squat (kg)	M	177.93	146.49	129.56	132.72	107.15	82.28	-	-	<0.001	0.562
	SD	39.20	34.68	16.42	25.45	26.28	19.87	-	-		
Relative Strength (1RM/Body Weight)	M	2.47	2.09	1.87	1.93	1.78	1.47	-	-	<0.001	0.379
	SD	0.57	0.50	0.30	0.34	0.41	0.26	-	-		
YOYO test	M	2368.89	2406.66	2269.31	2322.00	1978.28	1732.57	-	-	<0.001	0.244
Recovery level one (m)	SD	616.71	370.66	494.70	397.778	484.23	439.33	-	-		

Figure 2. Post hoc analysis of body composition variables between categories according to age, A) body weight, B) height, C) Percentage of fat mass and D) Percentage of muscle mass. a different with U21, b different with U18, c different with U16, d different with U15, e different with U14, f different with U13, g different with U12.

Figure 2 presents the post hoc analyses that show significant differences between age categories in body composition variables.

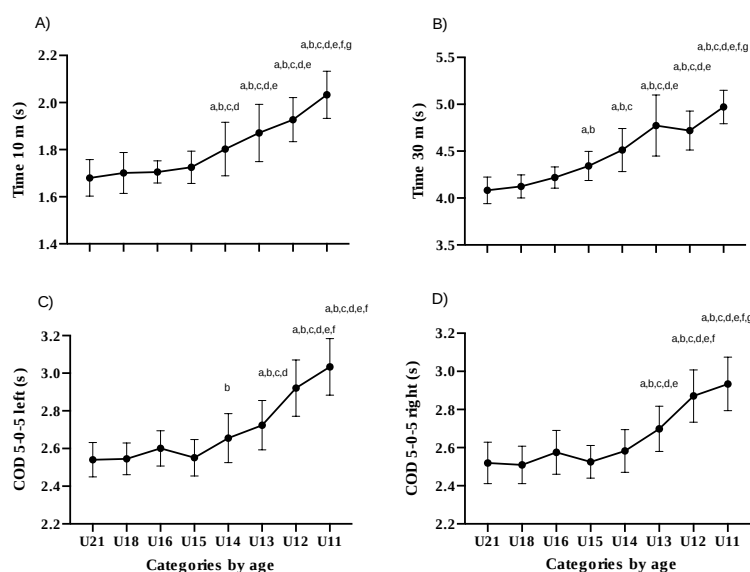


Figure 3. Post hoc analysis of running variables between categories according to age, A) time in 10 meters, B) Time in 30 meters, C) Change of direction with left profile and D) Change of direction with



right profile. a different with U21, b different with U18, c different with U16, d different with U15, e different with U14, f different with U13, g different with U12.

Figure 3 presents the post hoc analyses that show significant differences between age categories in career variables

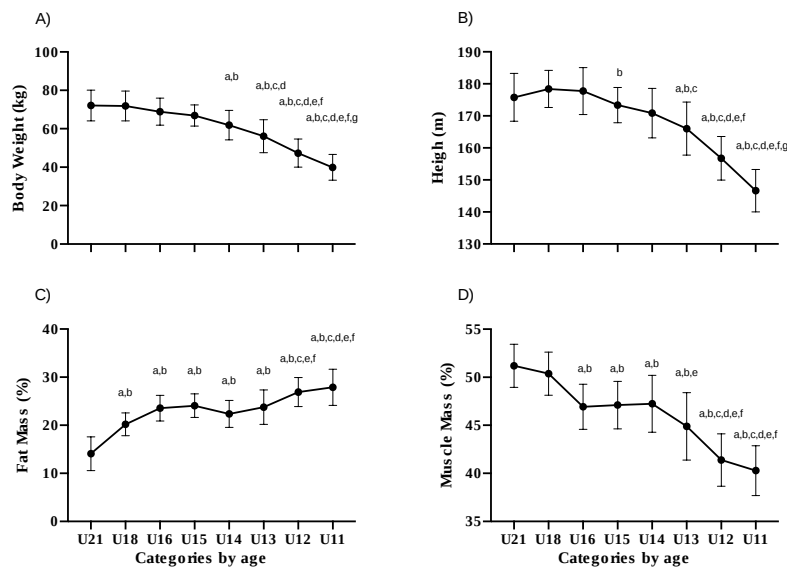


Figure 4. Post hoc analysis in neuromuscular variables between categories according to age, A) 1RM squat, B) Pull speed, C) Relative strength and D) Countermovement jump. a different with U21, b different with U18, c different with U16, d different with U15, e different with U14, f different with U13, g different with U12.

Figure 4 presents the post hoc analyses that show significant differences between age categories in neuromuscular variables.

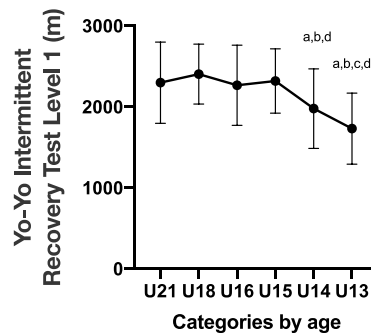


Figure 5 presents the post hoc analyses that show significant differences between age categories in aerobic performance

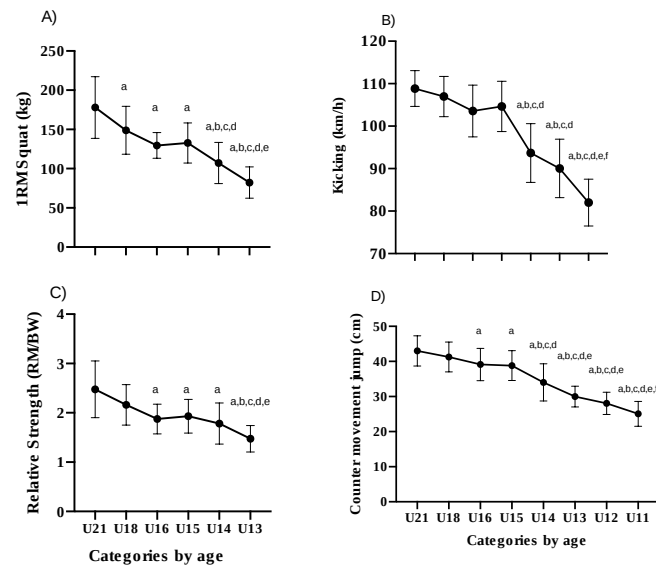


Figure 5. Post hoc analysis of aerobic performance variables between categories according to age. a different with U21, b different with U18, c different with U16, d different with U15, e different with U14, f different with U13, g different with U12.

Discussion

This study aimed to compare the body composition and physical performance of football players in formative categories, ranging from U11 to U21. The main findings related to body composition indicate a progression trend in composition variables such as body mass, muscle mass, and fat percentage. In the higher categories (U21 and U18), a more optimized composition was observed, characterized by greater muscle mass and lower fat percentage compared to the younger categories (U12 and U11). This pattern may be attributed to the combined effects of biological maturation, specialized training programs, and greater exposure to competitive demands (Segueida-Lorca et al., 2022). However, in the younger categories (U11 to U14), greater variability in body composition is identified, which could be associated with differences in maturation status and initial level of training (Towlson & Cumming, 2022). When compared with international normative data, the body fat percentage and muscle mass values in our U18 and U21 players are consistent with ranges reported in elite European academies (Lago-Peñas et al., 2011; Mujika et al., 2009), whereas younger categories show higher variability, similar to developmental patterns observed in longitudinal monitoring of Spanish and English youth footballers (Deprez et al., 2015). These findings highlight the importance of individualising and tailoring training programs during early developmental stages to enhance muscle mass gains and reduce excess fat (Suarez-Arrones et al., 2019).

On the other hand, the analysis of physical qualities shows a progressive development in all categories, reflecting the interaction between biological maturation and training. In the speed tests (T10 and T30), sprint times decreased with age, indicating a better performance in U21 and U18 categories. This highlights the importance of emphasizing running technique and the development of explosive strength in early stages to maximize acceleration and overall sprinting speed (Aloui et al., 2021; Amonette et al., 2014). Our results in U18 and U21 categories are comparable to sprint times reported for national-level youth players in France and Belgium (Buchheit, Mendez-villanueva, et al., 2010; Mendez-Villanueva et al., 2011), whereas U13–U15 players present slightly slower times than the reference data from English academies (Mujika et al., 2009), reinforcing the need for earlier emphasis on sprint mechanics. A similar trend was observed in the change of direction test (COD 505), where the higher categories (U15 to U21) demonstrate better times in the change of direction tests in both profiles. However, the results suggest a potential stagnation in the development of this skill, indicating the need for consistent and transversal

development throughout all categories (Aloui et al., 2021, 2021; Amonette et al., 2014; Pérez-Contreras et al., 2022). This plateau is also documented in normative COD data for youth elite footballers between 15–17 years (Taylor et al., 2019), suggesting that specific COD-focused training stimuli may be required beyond early adolescence.

Regarding the CMJ, previous research established a relationship between CMJ height and strength levels in athletes (Pérez-Contreras et al., 2022) and performance improving progressively with age (Villaseca-Vicuña et al., 2021). This suggests that the development of maximum strength in the older categories contributes to notable improvements in lower body power (González & Sánchez, 2018; Otero-Esquina et al., 2017). The CMJ heights in U18 and U21 players in our sample are within the upper range of values reported in international youth elite standards (Loturco et al., 2017), while the younger categories (U11–U14) are closer to the lower range described in developmental cohorts from Brazil (Marinho et al., 2020), confirming the progressive nature but also highlighting the gap to close with top-level benchmarks. A similar result was reported with the 1RM and 1RM/BW variables, where both absolute and relative strength values increased consistently, with the highest values observed in U21 and U1 athletes. This highlights the importance of well-structured and progressive strength training in the training process (Case et al., 2020; Ramirez-Campillo et al., 2018; Zabaloy et al., 2022). These strength values are also consistent with reference data for elite youth squads in Tunisia (Aloui, Hermassi, Hayes, Sanal Hayes, et al., 2021), reinforcing the adequacy of current strength training practices in older categories.

In relation to kicking performance, our results indicate an increase in speed up to the U15 category. Other studies analyzing this capacity have reported continued improvements in older categories, such as U17 (Pérez-Contreras et al., 2022; Rodríguez-Lorenzo et al., 2019). Further research is needed to corroborate these findings. For instance, Palucci Vieira et al., in addition to measuring the shot speed with a 3D video capture system, evaluated the accuracy of the shot, adding complexity to the task (Rodríguez-Lorenzo et al., 2015). On the other hand, Rodríguez-Lorenzo et al. examined the dominant and non-dominant legs, finding an increase to U16 in the dominant leg and from U16 to U18 in the non-dominant leg (Rodríguez-Lorenzo et al., 2015). When compared with international reference values, our U15 players' kicking speeds are slightly below those reported for elite U15–U16 squads in Australia and Europe (Hunter et al., 2022), suggesting the potential benefit of targeted kicking power interventions beyond this age.

Finally, regarding aerobic endurance (YoYo Test) reflect that the older categories exhibit greater aerobic capacity, likely due to more intense and specific training (Castagna, et al., 2010). The younger categories have shorter distances travelled, consistent with the physiological capacities in the development of these ages (Pérez-Contreras et al., 2022). In our case, this ability seems to stabilize in the U15 category. However, other studies have reported continued improvements in categories such as U16 (Buchheit et al., 2010) and while some findings are consistent with our results (Pérez-Contreras et al., 2022). These discrepancies may be attributed to differences in maturation among the groups analyzed, as well as the type of endurance test utilized. For example, the study that found differences between U16 and higher categories used an incremental field test (Buchheit et al., 2010). Therefore, a performance plateau in aerobic capacity appears to emerge around the U15–U16 categories. This stabilization is in line with normative YoYo IR1 results in elite European academies (Castagna et al., 2006; Deprez et al., 2015). Although our U15 and U16 values are slightly lower than those reported for elite youth squads in Belgium (Deprez et al., 2014), suggesting room for optimization in endurance development at this stage.

However, our study is not without limitations. Notably, the body composition data was not broken down by playing position. This could influence the variations observed as different positions demand distinct physical profiles. In addition, the lack of control over aspects such as the diet and lifestyle habits of the players could have affected the results. The cross-sectional design used in this study also limits the ability to establish causal relationships or determine individual developmental trajectories over time, in contrast to longitudinal approaches that allow tracking within-player changes and better understanding of growth and maturation patterns in youth athletes (Malina et al., 2015). In addition, no longitudinal analyses were performed, which prevents assessing how physical development changes over time in the same players. The data does not consider external factors, such as previous training load, sleep quality or fatigue levels. The sample includes only players from one club, which could limit the generalization of the results to other contexts or levels of competition. Moreover, some age

categories exhibited performance plateaus or even declines in certain variables, which may be associated with maturational differences, training history, or variations in competitive exposure (Lloyd & Oliver, 2012). These patterns were not initially expected and suggest that not all developmental progressions are linear (Malina et al., 2004). Future studies should explore the underlying causes of these deviations, potentially including biological maturation assessment and multi-club sampling to enhance external validity (Murtagh et al., 2018).

The insights from this study could be valuable for the sports community, specifically coaches and athletic trainers. Regular monitoring of body composition in youth categories could help identify specific deficiencies and enable more personalized interventions. In the higher categories, it is recommended to focus training programs on maintaining muscle mass and minimizing fat accumulation during the season, especially during periods of inactivity. Furthermore, it would be beneficial to design specific training programs by age category, emphasising running technique and the development of strength and power in youth categories. For example, in U11–U14, implementing twice-weekly sessions of plyometric and sprint drills with technical feedback could enhance acceleration mechanics, while in U15–U18, integrating progressive strength training (e.g., squat, hip thrust, Olympic lift derivatives) 2–3 times per week could support muscle mass and power development. Incorporating periodic evaluation tools, such as jump tests or change of direction, could also facilitate the monitoring of progress and enable adjustments to training loads. Additionally, where performance stagnation or regression is detected (e.g., COD performance in U15–U16), coaches could introduce targeted microcycles emphasizing COD drills under fatigue, resisted sprints, or technical re-education to improve efficiency. Special attention should be given to categories where performance stagnation or regression was observed, implementing targeted interventions to address possible gaps in training stimulus, technical execution, or physical maturation support (Asadi et al., 2018; Wrigley et al., 2014).

Conclusions

The results obtained in this study allow us to identify general trends in body composition and physical qualities of footballers according to age and category, rather than definitive patterns of progression, given the cross-sectional design and the fact that the sample comes from a single club. As players progress through the formative categories, significant improvements are observed in strength, power, speed, and aerobic endurance parameters, as well as a more optimized body composition with greater muscle mass and lower fat percentage. These changes reflect the influence of biological maturation and the cumulative impact of specific training. In particular, the top categories (U21 and U18) stand out for their higher performance in speed (T10 and T30), change of direction (COD 505), relative strength and aerobic capacity (YoYo test), which underlines the importance of a progressive approach in training planning to maximize the development of these physical capacities in the formative stages. However, the lower categories (U11–U14) present greater variability, which suggests the need for personalized interventions that consider individual differences in the maturation stage and initial level of the players. While several of these trends align with previously established developmental patterns in youth football, this study adds value by providing detailed, category-specific reference data from a professional club's formative system, which can serve as a practical benchmark for applied monitoring and training program design.

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