Use of Exploratory Factor Analysis to Assess the Fitness Performance of Youth Football Players

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Abstract

Perroni, F, Castagna, C, Amatori, S, Gobbi, E, Vetrano, M, Visco, V, Guidetti, L, Baldari, C, Luigi Rocchi, MB, and Sisti, D. Use of exploratory factor analysis to assess the fitness performance of youth football players. *J Strength Cond Res* XX(X): 000–000, 2022—Football performance involves several physical abilities that range in aerobic, anaerobic, and neuromuscular domains; however, little is known about their interplay in profiling individual physical attributes. This study aimed to profile physical performance in youth football players according to their training status. One hundred seven young male soccer players (age 13.5 ± 1.4 years; height 168 ± 7 cm; body mass 57.4 ± 9.6 kg; and body mass index 20.2 ± 2.1 $kg \cdot m^{-2}$) volunteered for this study. Players' physical performance was assessed with football-relevant field tests for sprinting (10 m sprint), vertical jump (countermovement jump), intermittent high-intensity endurance (Yo-Yo Intermittent Recovery Test Level 1, YYIRT1), and repeated sprint ability (RSA). The training status was assumed as testosterone and cortisol saliva concentrations; biological maturation was estimated using the Pubertal Development Scale. Exploratory factor analysis (EFA) revealed 3 main variables depicting anthropometric (D1, 24.9%), physical performance (D2, 18.8%), and training status (D3, 13.3%), accounting for 57.0% of total variance altogether. The level of significance was set at $p \le 0.05$. The RSA and YYIRT1 performances were largely associated with D2, suggesting the relevance of endurance in youth football. This study revealed that for youth football players, a 3-component model should be considered to evaluate youth soccer players. The EFA approach may help to disclose interindividual differences useful to talent identification and selection.

Key Words: endurance, field testing, soccer, talent identification, team sports, training load

Introduction

Football is an intermittent high-intensity team sport in which performance is affected by players' anthropometric profile (1) and the combination of physical, technical, and tactical skills (37). Football physical performance has been reported to be competitive-level dependent and affected by players' maturation status (37). The assessment of football-relevant physical fitness attributes was proposed as a valid procedure to guide training optimization and talent detection, selection, and development in football (23,38,39).

Consideration for field testing is based on the assumed construct of measuring players' physical capabilities in combination with their physical abilities. The former refers to the "nature," and the latter refers to a player's physical performance, "nurture." By combining these 2 constructs, field testing ideally requires knowledge of players' training status to account for training fatigue to obtain unbiased data. Specifically, training fatigue may lead to biased results when field tests guide training implementation and player selection. Accounting for the interaction between players' external (i.e., test results) and internal load (i.e., acute fatigue) may provide a more accurate picture of players' physical status. Internal load assessment may be a viable strategy to avoid biased field testing.

Although not sustainable by the general population, biochemical and hormonal profiling are considered valid and objective procedures to assess a player's training status (16,26). Specifically, the blood concentration of anabolic and catabolic hormones was assumed as a reference for training status (19). Their concentration was associated with field tests relevant to football performance, promoting the interest in their use as a surrogate measure of training status (32). Ideally, combining biochemical markers with football-relevant field tests may help hone knowledge of players' performance status, guiding training implementation and youth football player development.

Football performance is complex, requiring a variety of physical abilities in aerobic, anaerobic, and neuromuscular domains (37). The search for space and scoring opportunities at individual and team levels requires players to accelerate and decelerate according to the match scenario to sustain them for the entire match (37). Field tests have been proposed to profile relevant physical performance variables in young football players (7–9). Evidence was provided for the relevance (i.e., association with

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match game demands) of the ability to repeat sprints and intermittent high-intensity endurance (7–9,14). Accelerations and decelerations are physical abilities that relate logically to football performance (37). Linear sprinting over short distances has been used as a paradigm to evaluate players' ability to change speed and is considered functional in creating goal-scoring opportunities (13). Various forms of jumping were proposed as a paradigm to evaluate football players' neuromuscular performance, with vertical jumping assuming logical validity for heading (6).

Despite the interest in physical test constructs to track youth football players, there is still no information about their interplay in profiling individual physical attributes. The definition of the physical continuum of players concerning physical relevant performance attributes may be of paramount importance for talent detection, selection, and development. Therefore, this study aimed to profile physical performance according to training and maturation status in young football players, considering relevant match performance constructs. An association between physical performance, training, and biological status was assumed as a working hypothesis.

Methods

Experimental Approach to the Problem

A descriptive design was considered to enable a functional analysis to profile group and individual physical performance in a professional youth football team. Physical performance was assessed considering football-relevant field tests depicting players' neuromuscular, anaerobic, and aerobic abilities. Neuromuscular abilities were tested as vertical jump (i.e., countermovement jump, CMJ) and line sprint over 10-m performance. The ability to repeat short sprints with incomplete recovery time [i.e., repeated sprint ability (RSA)] was assumed as a paradigm of a player's functional anaerobic performance. To warrant logical validity, a test protocol with sprints (7 × 30 m with 25 seconds active recovery) including 3 changes of directions was considered. The Yo-Yo Intermittent Recovery Test Level 1 (YYIRT1) was assumed to reflect players' high-intensity endurance and represent the aerobic ability construct.

Field tests are the results of causal variables underpinning physical performance during the training process. The association between physical performance and training stress (i.e., internal load) may be helpful in profiling players' physical preparedness. Players' internal load was assessed by evaluating training load-relevant biochemical markers such as testosterone and cortisol.

Anthropometric assessments, physical performance evaluations, and salivary and blood sampling were performed over 3 days in the following order: day 1: salivary sample collection and anthropometric measurements; day 2: CMJ, 10-m sprint, and RSA performance evaluation; and day 3: YYIRT1 performance evaluation. Players were accustomed to the procedure used in this study as being part of their clubs' evaluation follow-up. Salivary and blood sample collection and anthropometric assessments were organized in the morning (between 8:00 and 8:30 AM), while physical evaluations were performed in the afternoon (between 4:00 and 5:00 PM). To reduce the impact of weather conditions (36), experimental evaluations were performed on an artificial turf approved for national-level competitions under similar environmental conditions (temperature: 18–20° C; humidity: 50–60%). Twenty-four hours before the testing session, subjects avoided any high-intensity activities, while they avoided food and drink the hour before testing. When each study subject arrived at the training center, they were led to the medical room, where their anthropometric measurements (body mass and height) as well as salivary and blood samples were taken. The measure of pubertal development was obtained by a self-administered Rating Scale for Pubertal Development (PDS) (29), which is a reliable and valid brief questionnaire, translated in its Italian version by Perroni et al. (28), and previously used to make comparisons between the pubertal development and the football capabilities of different age groups (25,27) in a fast and simple manner. Before the test session, all youth football players underwent a standardized warm-up period (15 minutes) developed by the technical club's coaches: jogging at 40–60% of individuals' theoretical maximal heart rate (calculated as 220 age), strolling locomotion, and stretching. Considering the nature of football activities, we used the CMJ (5), 10-m sprint, and RSA (4) tests to evaluate the "explosive efforts" and "high-intensity efforts" players' capacities, while the YYIRT1 (3) was used to estimate the aerobic capacity of football players. Researchers verbally encouraged the football players to perform the test with maximal concentration and maximum effort during each test.

Subjects

One hundred seven male young soccer players (age 13.5 ± 1.4 years; height 168 ± 7 cm; body mass 57.4 ± 9.6 kg; and body mass index (BMI) 20.2 ± 2.1 $kg\cdot m^{-2}$; the variables are reported as mean ± SD) from some elite youth football teams voluntarily participated in this study. Players were stratified into game roles according to playing position: 32 strikers, 26 midfielders, and 49 defenders. Players had no less than 6 years of experience in football (competitive and training) and trained at least 3 times per week (1.5-hour training session), playing a match (60-minute match) during the weekend. All the players lived in their own homes with their respective families. Before the commencement of this study, written informed consent was obtained from all the players and their parents/guardians after a detailed explanation of the risks and benefits involved in this research. All the subjects and parents/guardians were aware that they could withdraw from this study at any time without penalty. The Bioethics Committee of the University of Turin (Study Protocol No. 134685) approved this study; all the procedures were performed following the ethical standards of the institutional and national research committees and with the 1964 Declaration of Helsinki and its later amendments. Data collection was performed at the beginning of the competitive season (October). No strenuous activity and/or training outside of their regular training schedule were declared by subjects for the 2 days before testing procedures took place.

Procedures

Body mass (kg) and height (m), without shoes and heavy clothing, were measured using an electronic scale and a stadiometer (Seca 702, Seca GmbH & Co. KG, Hamburg, Germany) with an accuracy of ±0.1 kg and ±0.1 cm, respectively; BMI was then calculated.

Pubertal Development Scale. In the PDS, completed individually with the presence in the room of an investigator to assist if required, youth football players were asked to describe the rate of the amount of change or development they had experienced concerning to several physical characteristics (body hair growth, facial hair growth, skin changes, voice deepening, and growth spurt) associated with pubertal maturation. Ratings on each characteristic were

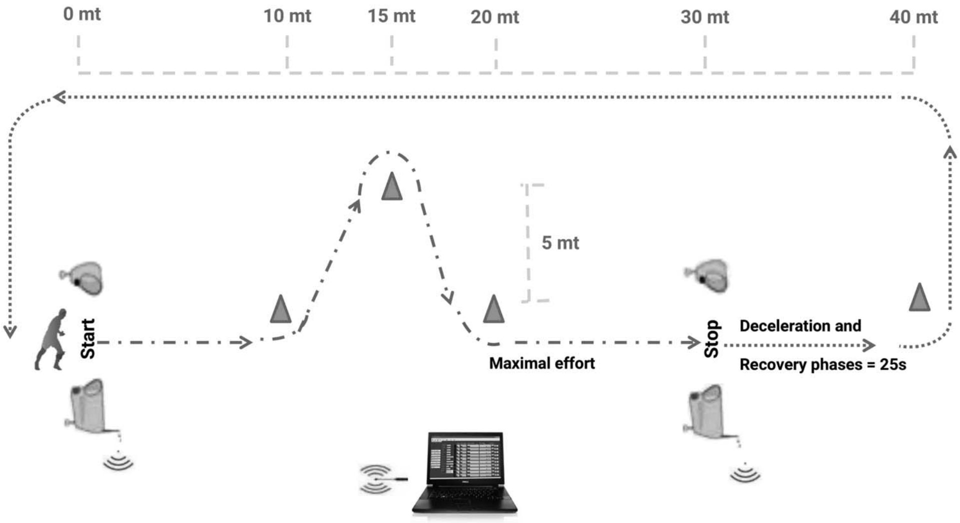

Figure 1. Path of the repeated sprint ability test.

made along a 4-point Likert scale. Development status scores are derived by summing the ratings on the 5 characteristics and then dividing by 5 to retain the original metric.

Performance Evaluation. To measure the explosive effort of lower limbs, youth football players performed a CMJ test on an optical acquisition system (Optojump, Microgate, Udine, Italy), which is triggered by the feet of the subject at the instant of take-off and at contact on landing (10^{-3} seconds of resolution). Starting from the standing position, football players had to bend, as quickly as possible, their knees to a 90° angle and, immediately after, perform a maximal vertical jump (stretch-shortening cycle). During the jump phase, subjects had to (a) keep their hands on their hips to avoid any effect of arm swing, (b) avoid any knee or trunk countermovement, (c) keep their body vertical, and (d) land with their knees fully extended. If the jump failed to adhere to the protocol, the trial was repeated, and the highest of 3 correct jumps was used for further analysis. The jump height was calculated in real time by specific software (18). Slinde et al. (33) showed high test-retest stability coefficients (range 0.80–0.98) for the vertical jump test.

Considering that previous studies (10,11) confirmed the validity and reliability of the 10-m sprint test using electronic timing gates, we used a dual infrared reflex photoelectric cell system (Polifemo, Microgate) to evaluate 10-m performances. Photocells were positioned 20 m apart, with the first timing gate positioned at 0.5 m from the start. For each test, subjects performed 3 trials (receiving verbal encouragement) with a 5-minute recovery period between trials. Their best performance was used for statistical analysis.

The YYIRT1 is considered a reliable and valid measurement of match-related fitness performance in football (20). Groups of 10–12 subjects repeated 20 m runs back and forth between starting, turning, and finishing line at a progressively increased speed controlled by an audio metronome. Between each running bout, players had a 10-second active recovery period (decelerating and walking back to the starting line). If the subject could not maintain the required speed and failed twice to reach the finishing line in time, the distance covered was considered the test result (20). Fanchini et al. (12) showed an intraclass correlation coefficient (ICC) of 0.78 (from 0.61 to 0.89) for YYIRT1.

To evaluate the ability of repeated sprints, we used the Bangsbo's test (2), consisting of 7 × 30-m sprints (with 3 changes of direction), deceleration as quickly as possible after the finishing line (maximal space of deceleration phase = 10 m), and 25 seconds of active recovery in self-paced jogging between sprints to

Table 1

Descriptive statistics (mean ± standard deviation) of measured outcome variables, stratified for soccer role.

Variables	Defender ($n = 49$)	Midfielder ($n = 26$)	Striker ($n = 32$)
Height (cm)	171 ± 6	164 ± 5	166 ± 8
Body mass (kg)	61.5 ± 9.1	54.3 ± 7.6	53.6 ± 9.5
Body mass index ($kg\cdot m^{-2}$)	21.0 ± 2.0	20.1 ± 1.9	19.2 ± 1.9
Pubertal development scale	2.57 ± 0.48	2.28 ± 0.61	2.37 ± 0.62
CMJ (cm)	30.4 ± 3.3	29.5 ± 3.6	31.1 ± 4.3
YYIRT1 (m)	5,591 ± 373	5,643 ± 276	5,541 ± 372
RSA Total Time (s)	48.9 ± 2.1	48.9 ± 1.8	48.6 ± 1.7
RSA index	3.89 ± 2.09	3.90 ± 1.32	4.98 ± 2.65
10-m sprint (s)	1.82 ± 0.10	1.83 ± 0.09	1.80 ± 0.11
Testosterone ($ng\cdot ml^{-1}$)	69.9 ± 44.7	50.0 ± 34.6	66.9 ± 43.5
Cortisol ($ng\cdot ml^{-1}$)	2.26 ± 1.27	2.09 ± 1.13	1.99 ± 1.23
T/C ratio ($ng\cdot ml^{-1}$)	42.3 ± 38.2	29.8 ± 26.8	42.9 ± 31.1

CMJ, countermovement jump; YYIRT1, Yo-Yo Intermittent Recovery Test Level 1; RSA, repeated sprint ability; T, testosterone; C, Cortisol.

Table 2

Correlation matrix among variables.

	Age	Height	Body mass	BMI	PDS	CMJ	10-m sprint	YYIRT1	RSA TT	RSA index	T	C	T/C ratio
Age	1	−0.218	−0.121	0.004	0.022	−0.152	0.102	−0.174	0.124	0.051	0.117	0.042	0.077
Height	—	1	0.885	0.622	0.533	0.198	−0.366	0.038	−0.203	−0.074	0.332	0.054	0.242
Body mass	—	—	1	0.912	0.602	0.176	−0.333	−0.129	−0.121	0.037	0.283	−0.050	0.239
BMI	—	—	—	1	0.585	0.139	−0.252	−0.237	−0.050	0.118	0.197	−0.128	0.202
PDS	—	—	—	—	1	0.120	−0.187	0.000	−0.174	−0.044	0.197	−0.081	0.245
CMJ	—	—	—	—	—	1	−0.354	0.408	−0.397	0.035	0.189	0.060	0.066
10-m sprint	—	—	—	—	—	—	1	−0.228	0.419	−0.055	−0.124	0.007	−0.068
YYIRT1	—	—	—	—	—	—	—	1	−0.499	−0.412	0.000	0.066	0.018
RSA TT	—	—	—	—	—	—	—	—	1	0.353	−0.072	0.135	−0.141
RSA index	—	—	—	—	—	—	—	—	—	1	0.094	0.111	−0.020
T	—	—	—	—	—	—	—	—	—	—	1	0.119	0.649
C	—	—	—	—	—	—	—	—	—	—	—	1	−0.494
T/C ratio	—	—	—	—	—	—	—	—	—	—	—	—	1

BMI, body mass index; PDS, pubertal development scale; CMJ, countermovement jump; YYIRT1, Yo-Yo Intermittent Recovery Test Level 1, RSA: repeated sprint ability; RSA TT, repeated sprint ability total time; T,testosterone; C, cortisol.

return to the starting line for a new start (ICC = 0.94, power = 0.99, and effect size = 0.84, respectively) (Figure 1).

To evaluate the single sprint time, we used a photoelectric cell system (S30-A; Digitech, Trieste, Italy) positioned at the starting and finishing lines at 1.4-m height and 2 m apart. Then, we calculated the total time (RSA Total Time) consisting of the sum of sprinting scores over 30 m and the fatigue index percentage (RSA index) (%IF = [(total sprint time/lowest sprint time × 7) × 100] − 100) (15,34). Players had to position their front feet immediately before a line set 0.5 m from the photocell beam to avoid an undue switch-on of the timing system. To ensure maximal effort from each player, verbal encouragement was given by researchers during tests.

Salivary Sample Collection and Analysis. Subjects were instructed to collect saliva samples with a cotton swab and a saliva collecting tube (DRG International Inc.) and to transport them immediately to the laboratory (10 minutes by car from the training center) in a cooler bag, where they were centrifuged (IEC FL 40, Thermo Scientific) at 4° C, 3,000 rpm for 15 minutes. To avoid contamination with food debris and prevent sample dilution, we asked each subject to rinse their mouth with water at least 15 minutes before collection. To measure salivary testosterone (sT) and salivary cortisol (sC) after centrifugation, saliva samples were stored in the fridge at −20° C until they were analyzed in duplicate using commercially available kits (DRG Diagnostics, Marburg, Germany) according to the manufacturer's protocol. The sensitivities of sT and sC assays were 2.63 $pg \cdot ml^{-1}$ (range of detection: 0.94–1,000 $pg \cdot ml^{-1}$) and 0.537 $ng \cdot ml^{-1}$ (range of detection: 0.537–80 $ng \cdot ml^{-1}$), respectively. The interassay and intra-assay coefficients of variation for sC measurements were 8 and 5%, respectively, and 10 and 5% for sT measurements.

Statistical Analyses

For quantitative variables, mean and standard deviation were reported. A correlation matrix was initially conducted to explore multicollinearity among variables, using the variance inflation factor as a metric (cut-off value >5). Body mass (VIF = 382) was

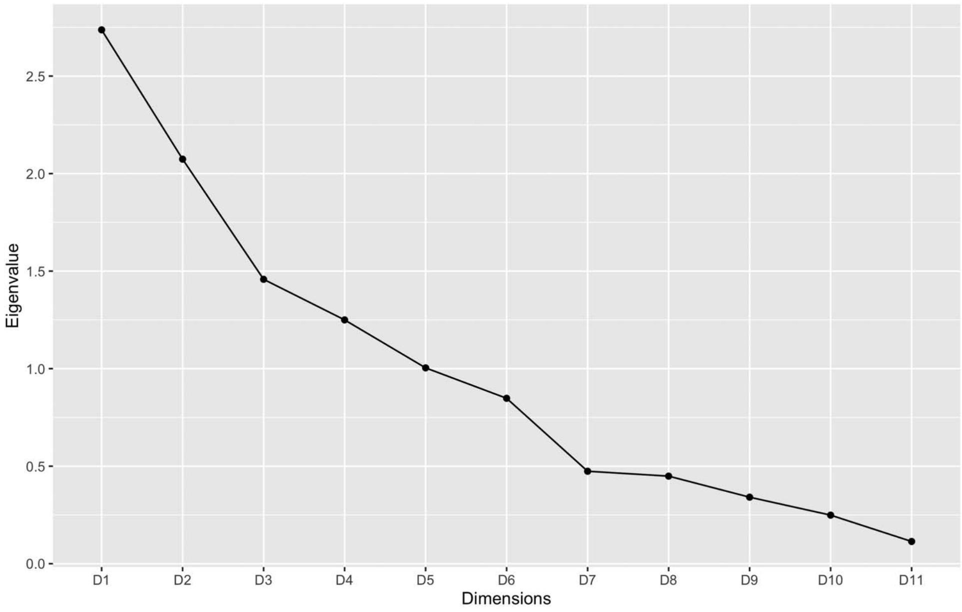

Figure 2. Scree plot of explained variance for each factor (D).

Table 3

Pattern coefficients of the factors after promax rotation.*

Variables	D1 (24.9%) Anthropometrics	D2 (18.8%) Performance	D3 (13.3%) Training status
Age	—	—	—
Height	0.854	—	—
Body mass index	0.850	—	—
Pubertal development scale	0.747	—	—
CMJ	—	0.549	—
YYIRT1	—	0.857	—
RSA Total Time	—	−0.775	—
RSA index	—	−0.597	—
Testosterone	0.376	—	0.476
Cortisol	—	—	−0.711
T/C ratio	—	—	0.891

*Only values above |0.35| are reported.

T: testosterone; C: cortisol; CMJ: countermovement jump; YYIRT1: Yo-Yo Intermittent Recovery Test Level 1; RSA: repeated sprint ability.

removed in this phase because of high correlation values with height and BMI; all the remaining variables showed a VIF below the cut-off value. An exploratory factor analysis (EFA) was then conducted on age, height, BMI, cortisol, testosterone, testosterone/cortisol ratio, CMJ, YYIRT1, RSA Total Time, RSA index, 10-m sprint, and PDS score. A promax solution yields results that make it easy to identify each variable within a single factor. The Kaiser-Meyer-Olkin (KMO) test was used to assess the factorability of the data (cut-off set at KMO = 0.5). The number of factors was evaluated using the Kaiser criterion (eigenvalues over 1) and scree plot. This solution yielded a high cross loading of 10-m sprint between the first 2 dimensions; thus, it was decided not to include this variable in the EFA, which has been performed again without it. The scores of each subject, considering first, second, and third factors (Ds), were plotted in a 3D scatter plot to visualize the characteristics summarized by EFA analysis, and the 95% confidence ellipses highlighted subgroups of athletes stratified by their role in the team (defenders, midfielders, or strikers). Moreover, 2D scatterplots were also reported. Playing position differences in Ds obtained were checked using multiple analysis of variance, where the predictive factor was the playing position (defender, midfielder, or striker), and the dependent variables were the scores of the 3 Ds. Partial eta squared was also reported as effect size values. An LSD post hoc test was used to compare the 3 playing positions. The level of significance was set at $p \leq 0.05$. All processing and graphics were obtained using Microsoft Excel, *stats*, *car*, *rgl*, and *ggplot2* packages of R Studio.

Results

Descriptive statistics for all the variables collected are presented in Table 1. A correlation matrix (Table 2) was computed among all the collected variables. As explained above, mass and 10-m sprint were not included in the EFA. The KMO value was 0.518, confirming the factorability of the data, although the value is close to the accepted cut-off value. Both scree plot and eigenvalues (with values >1) support the conclusion that the initial correlation matrix can be reduced to 3 factors (or dimensions; Ds), explaining 57.0% of the variance (Figure 2).

The first factor (D1) accounted for 24.9% (eigenvalue = 2.74) of the total variance in the data sets. The results showed that D1 was positively correlated with height, BMI, PDS, and marginally testosterone: This first component could be named “anthropometrics.” The second factor (D2), which accounted for 18.8% (eigenvalue = 2.07) of the total variance, showed a positive correlation with CMJ height and YYIRT1 distance and a negative correlation with both RSA Total Time and RSA index: This component could be defined as “physical performance.” The third factor (D3) represented 13.3% (eigenvalue = 1.46) of the total variance. The D3 was negatively correlated with sC and

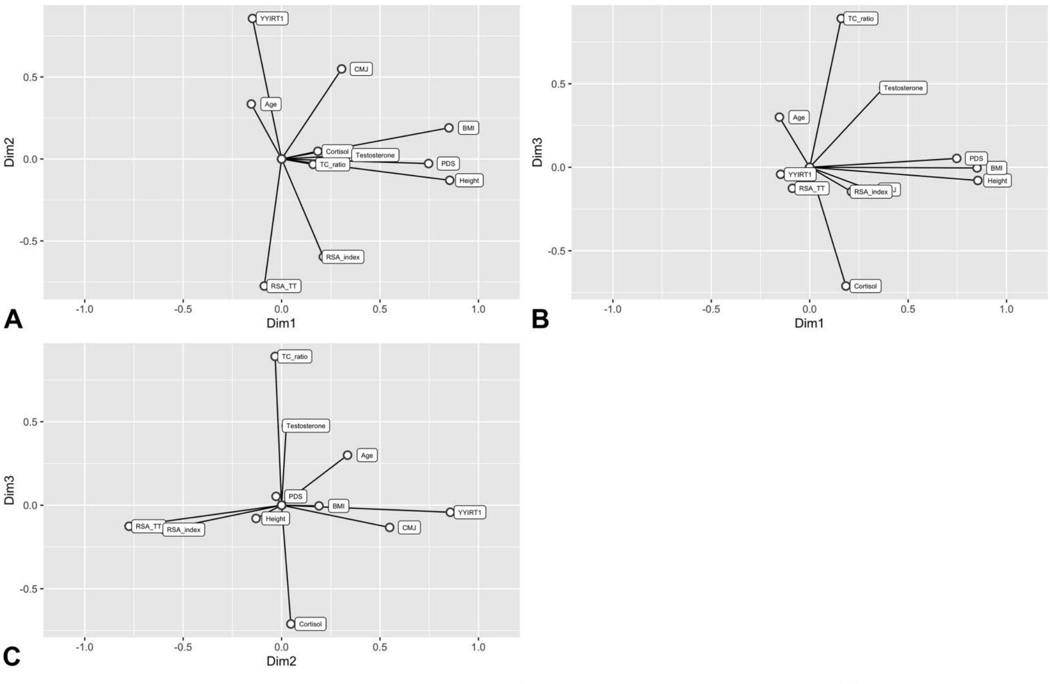

Figure 3. Variables’ correlation plots after promax rotation. A) Anthropometrics and performance; (B) Anthropometrics and Training status; (C) performance and training status.

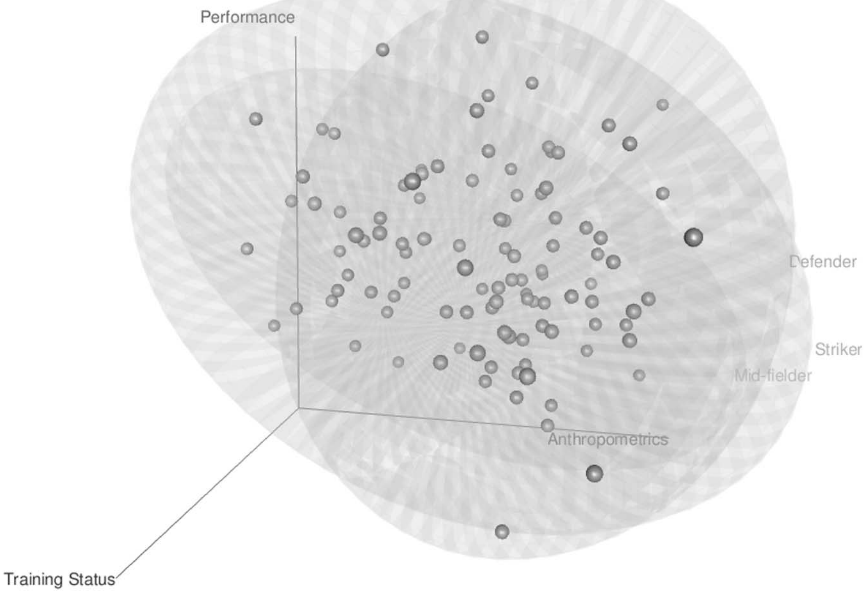

Figure 4. Plot of individuals. Individuals with a similar profile are grouped.

positively correlated with sT and sT/sC ratio: This last component could be referred to as "training status." The pattern coefficients of the factors are presented in Table 3. Notably, age did not enter into any factor.

In Figure 3, the correlation plots of all 3 combinations among Ds are reported, and they can be interpreted as follows: positively correlated variables are grouped, negatively correlated variables are positioned on opposite sides of the plot origin, and the distance between variables and the origin measures the quality of the variables on the factor map. Variables far from the origin are well represented on the factor map.

We used the score plot presented in Figure 4 to evaluate the characteristics of each subject for the values of each D. Different playing positions were reported in different colors, and each subject was placed on a point, which describes the characteristics summarized by the Ds. The confidence ellipses relating to the players' playing position distribution did not show substantial between-group differences, even if defenders showed a different ellipse's major axis orientation. D1 scores were different between the playing positions ($F_{(2,\ 104)} = 6.609$; $p = 0.002$; $n^2_p = 0.113$), but no significant differences were found for D2 ($F_{(2,\ 104)} = 0.989$; $p > 0.05$; $n^2_p = 0.0002$) and D3 ($F_{(2,\ 104)} = 0.647$; $p > 0.05$; $n^2_p = 0.008$). Post hoc comparisons revealed significant differences in D1 scores (anthropometrics) between defenders and midfielders ($p = 0.001$) and between defenders and strikers ($p = 0.014$). Defenders reported higher scores (0.35 ± 0.84) with respect to the other playing positions (−0.43 ± 0.97 and −0.19 ± 1.09, respectively, for midfielders and strikers). No differences emerged between midfielders and strikers ($p > 0.05$).

Discussion

This is the first study to examine the relationship between relevant physical match performance constructs and biological indicators of training status in young football players. The EFA was considered a convenient tool to cluster variables assumed to be relevant to youth football development. Data analyses revealed that football players' status might be explained by 3 main factors, accounting for approximately 60% of the total variance, namely

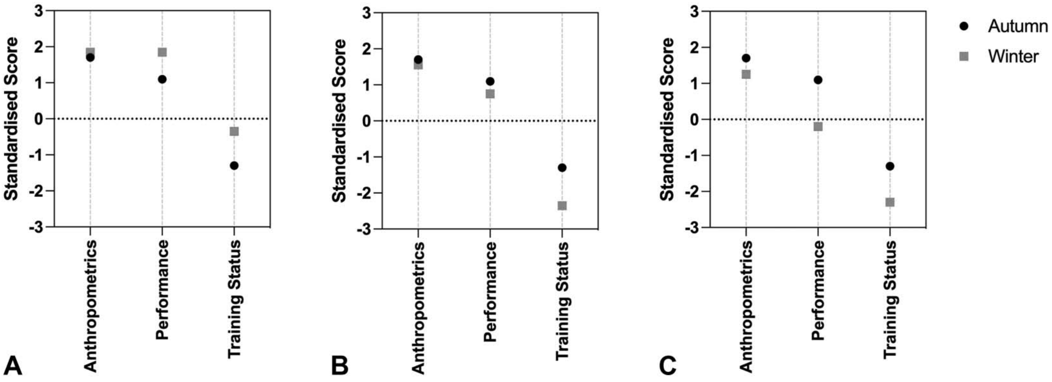

Figure 5. Explanatory view of the scoring of a single player obtained from EFA analysis, in three different hypothetical situations (A: good adaptation; B: training overload; C: non-functional overreaching).

anthropometric (D1), performance (D2), and training status (D3) factors. Interestingly, when dealing with 14–15-year-old youth football players, the EFA revealed a clear distinction between the nature of the considered variables, implying construct independence. Youth football talent identification and selection may be biased by players' maturation (17). As expected, a large association with D1 was reported for BMI and height.

To lessen selection bias, maturation-independent field tests should be preferable when testing for talent identification and selection during adolescence. In this study, aerobic and anaerobic endurance variables were revealed to feed D2 (i.e., physical component) and, together with CMJ, were not explaining other factor (D1 or D3) variance. Accounting for 18.8 and 13.3% of group total variance, physical and training status revealed a lower weight in intersubject variability, confirming the relevance and associated bias potential of maturation in characterizing youth football players.

It was reported that the anthropometrical profile of the players was associated with measures of match-related performance and that teams with higher fitness levels, and a lower percentage of body fat had a higher league ranking (1). Sporis et al. (35) reported that the anthropometry of youth football players differs regarding the playing position. Various studies on football players (30,31) showed that height and body mass are important performance factors. This study found a higher value for height and BMI in D1 compared with the other variables.

With the first 3 Ds (which combined explained 57.0% of the variance in our data set), it was possible to highlight variables that could resume anthropometric, performance, and training status determinants. In addition, EFA potentially enabled selecting which tests should be comprised within a testing battery, removing those that share similar information.

Considering the performance testing battery, within D2, YYIRT1 and CMJ showed the highest positive contributions, confirming these variables' importance in football. This finding confirms previous studies (21,24,30) reporting endurance capacity and explosive ballistic movement as predisposing to better game performance and a successful professional football career.

The role of sT and sC in tracking physical stress and performance has been well documented, with the sT/sC ratio being positively related to changes in physical performance (balance of anabolic/catabolic activity) and revealing a useful tool in the early detection of overtraining. Therefore, a dose-response relationship between training load variations and fitness status changes should be monitored in physical and physiological terms during all phases of the agonistic season to justify possible problems and/or variations in players' fitness status. This study's results aligned with the reported studies, with T/C being almost perfectly associated in D3.

To implement talent identification, the football club manager should develop the youth football academy with a specific training system that provides adequate physical development, reduces the risk of injury, promotes health, and leads players to the professional level. Given the multifactorial nature of football performance, the need for a construct-based process may pique the interest of all those involved in the development of young players. By reducing the components of multivariate data sets, EFA provides a fast and short visualization and interpretation of the qualities of football players, which can help the strength and conditioning coach to maximize the knowledge of their athletes and develop adequate training programs (22). In Figure 5, we report an example of how EFA scores could be used to monitor training adaptation over time. The scores of the same subject over 2 time points (autumn vs. winter) are represented in 3 different hypothetical situations. In panel A, the player shows good adaptation to the training loads because both the performance and training status scores improved. Panel B shows a worsening of the training status (which could indicate a prevalence of catabolic activity) but no significant changes in performance: This could indicate a situation of training overload, and the player may need to recover to fully adapt to the training loads. Finally, in panel C, a worsening of all the 3 characteristics is present: A significant decrease in performance, accompanied by training status disturbances, may be representative of a status of nonfunctional overreaching or even overtraining, suggesting that a complete period of recovery should be prescribed for the player.

Understandably, our study was subject to several limitations. First, the population was limited to youth football players of the same category and chronological age. Second, the results depend on the reproducibility of the variables analyzed, which were exclusive of physical and physiological nature without technical, tactical, and psychological factors. Thus, further research is needed to ascertain the utility of EFA to reduce the dimensionality of data in multifactorial sports such as football and to determine the necessity of including other aspects in future testing sessions.

Practical Applications

Evaluation and monitoring of athletes are important aspects of training periodization because the results can provide information to establish short-term and long-term targets. Starting from a large portion of data, using EFA can allow one to compare multiple qualities and recognize the differences between groups and/or phases of the competitive season easily and quickly. These findings suggest that systematic assessment of the multiple physical qualities is important for the regular development of youth football players without injury risk and to identify and develop talent.

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