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RESEARCH ARTICLE

Is Self-Administered Rating Scale for Pubertal Development a Predictor of Countermovement Jump in Young Soccer Players?

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Abstract:

Objective:

Considering that in Young sport competitions children are divided according to their chronological age, the aim of this study was to examine the correlation among chronological age and Self-Administered Rating Scale for Pubertal Development (PDS), anthropometry (Body Mass Index -BMI-, percent body fat -%BF-, fat free mass -FFM-), and Countermovement jump (CMJ) measures.

Methods:

112 young soccer players (age: 14±2 yrs; height: 1.68±0.11 m; weight: 60.3±11.6 kg; BMI: 21.3±2.5 $kg \cdot m^{-2}$) grouped in "Giovanissimi" (12-14 yrs), "Allievi" (15-16 yrs), and "Juniores" (>17 yrs), categories were evaluated. Pearson correlations and stepwise multiple regression analysis among variables were calculated considering all subjects and within categories. The internal consistency of PDS was determined by Cronbach's α coefficient (Cα). Considering all subjects, PDS showed an excellent Cα (0.89) and significant correlations with sub-category (r=0.66), age (r=0.67), %BF (r=-0.31), FFM (r=0.71), and CMJ (r=0.55). Within "Giovanissimi" category, significant correlations were found between PDS and age (r=0.56), CMJ (r=0.33), FFM (r=0.63), and sub-category (r=0.55). In "Allievi", PDS showed correlations with CMJ (r=0.46), FFM (r=0.42), and %BF (r=-0.45). In "Juniores" no significant correlations between PDS and other variables were present. The regression model with sub-category, PDS, and %BF as predictors explained 41% of the variance of CMJ in all subjects. In the "Allievi" category the PSD was the only predictor explaining the 18% of the CMJ performance variance.

Results:

PDS can provide useful information for the coach to create individual conditioning programs taking into account the growth problems of young soccer players and to minimize the risk of an excessive workload.

Keywords: Anthropometric, Puberty, Countermovement jump measures.

1. INTRODUCTION

Soccer is the most popular sport in the world especially among children. Despite numerous studies on adults soccer players [1 - 3] highlighted the combination of high levels of physical, technical and tactical skills during a soccer match, the physical performance required during a young soccer match is different with respect to adults and among young according to their chronological age. A number of studies [4 - 7] showed a high internal load in young soccer match,

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and a significant influence of age and playing position on the distances covered and the intensity of running during a young soccer match.

Considering the nature of the jumping activities and the frequency with which they occur in a typical soccer match, the countermovement jump (CMJ) is considered a good predictor of explosive capability and it is amongst the most widely performed movement to assess lower limb power [8 - 10]. In fact, the advantages of CMJ are that is a much more natural jumping movement and that the leg muscles reach a higher level of activation and force before they start to shorten [11]. Mujika *et al.* [12] showed that CMJ performance was sex and competitive level dependent in Spanish professional club.

Puberty is a complex biologic process that involves nervous and endocrine development within a relatively short period, and it has an impact on anthropometric, physiological and psychological changes. Considerable differences in pubertal development between young can be described in terms of timing (how the individual children maturation is compared to their same-sex and age), tempo (how quickly or slowly individuals progress to full sexual maturity) [3, 13]. In fact, a marked increase in physical performance occurs during and after puberty [14] with psychological changes (*i.e.* motivation, cognitive, and socio-emotional characteristics) that have a better adjustment in post-pubertal than in pre-pubertal boys [15]. Within single year chronological age groups, an advanced biological maturity is associated with advantages in anthropometric (*i.e.* body size, fat free mass) and physical fitness (*i.e.* aerobic power, muscular strength, and speed) variables [13, 16 - 18]. Perroni *et al.* [19] reported significant differences in categories, sub-categories and playing position between anthropometric values during development. These authors [20] have highlighted, in a preliminary study, the importance to assess the pubertal development in youth soccer categories.

Considering that, the young sport competitions are divided in categories and sub-categories according to chronological age, and that the ability of the lower limbs muscles to produce power is an important fitness component for soccer players [8], the aims of this study were: 1) to examine the relationship among chronological age, CMJ, and development status evaluated by a Self-Administered Rating Scale for Pubertal Development (PDS); 2) to assess if the PDS could be a predictor of CMJ in young male soccer players.

2. METHODS

2.1. Participants

We tested 112 young male soccer players (age: 14±2 yrs; height: 1.68±0.11 m; weight: 60.3±11.6 kg; BMI: 21.3±2.5 $kg \cdot m^{-2}$), recruited from an Italian Young Soccer Club, voluntarily to participate in this study. The participants were engaged at the beginning period of the Italian competitive soccer season (*i.e.*, September to October), they were homogeneous with regard to their training status (at least three days and one match per week for the previous 1 months), and none of the participants underwent any strenuous activity and training outside of their normal training schedule.

Since Italian young soccer competitions are organized into annual age groups according to chronological age, in the Young Soccer Club all soccer players are grouped in: “Giovanissimi” (age: 12.94 ± 0.86 yrs -range: 12-14 yrs-; height: 1.63 ± 0,11 m; weight: 54.77 ± 10.14 kg), “Allievi” (age: 15.42 ± 0.50 yrs -range: 15-16 yrs-; height: 1.75 ± 0.06 m; weight: 65.41 ± 9.04 kg) and “Juniores” (age: 17.44 ± 0.63 yrs - range: 17-19 yrs-; height: 1.75 ± 0.05 m; weight: 71.30 ± 8.99 kg) soccer players. In addition, “Giovanissimi” and “Allievi” are divided in 3 (“Giovanissimi A”= 14 years, “Giovanissimi B” = 13 years, and “Giovanissimi C” =12 years) and 2 (“Allievi A” = 16 years, and “Allievi B” =15 years) sub-categories, respectively. No sub-categories are present in “Juniores” (older than 17 years).

2.2. Procedures

Anthropometric, pubertal development, and vertical jump values of Italian Young Soccer Club were determined to evaluate the relationship among the chronological age, explosive performance and development in young soccer players. Tests were performed in the same testing session and sequence (pubertal development, anthropometric, and jumping evaluations), with 15-minutes rest among them. Before jumping evaluations, the soccer players performed a standard 15-minute warm up (jogging at 40-60% of maximal heart rate, strolling locomotion and 2-3 repetitions of self-administered submaximal jump). To reduce measurement variation, the same experienced investigator examined all subjects.

The club considered this evaluation as a routine exam of their young soccer players. All soccer players were tested at the beginning of the Italian competitive soccer season in the last week before the first official match. All procedures performed were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. In this way, the study protocol was approved by the University Scientific Commission and was carefully explained to each adolescent and their parents provided their written informed consent.

Weight and height were measured in light clothes, without shoes, using an electronic scale (±0.1 kg) and a stadiometer (±0.1 cm) (Seca 702, Seca GmbH & Co. KG, Hamburg, Germany). Body Mass Index (BMI) was used to assess weight relative to height and is calculated by dividing body mass by the squared height (kg/m^2).

Measurement of skinfold thickness to the nearest 0.1 mm was used to estimate body composition. Skinfold measurements of triceps, subscapular and anterior suprailiac were taken in triplicate on the right side of the body using a Harpenden caliper (St. Albans, UK), and the average value used for calculation. Equations of Slaughter and colleagues [21] was used to estimate percent body fat (%BF) in Pre-pubescent, Pubescent, and Post-pubescent, whereas fat free mass (FFM) was calculated as follows: FFM (kg) = weight*(100-%BF) / 100.

The measure of pubertal development (PDS) was obtained by a reliable and valid brief Self-Administered Rating Scale for Pubertal Development [19, 22 - 24]. Soccer players were asked to answer a questionnaire, on a 4-point scale ranging from "1" (without development) to "4" (development completed), regarding the amount of change or development compared to different physical characteristics (body and facial hair growth, skin changes, deepening voice, and growth spurt) associated with pubertal maturation. PDS scores were derived by summing the ratings done on the five characteristics and then dividing by five. In addition, a Pubertal Status (PS) score was obtained on the basis of reported values of body hair growth, facial hair growth, and voice change. PS have been classified in five pubertal status categories: pre-pubertal (a combined score of "3"); beginning pubertal (a combined score of "4" or "5"); mid-pubertal (a combined score of "6", "7" or "8"); advanced pubertal (a combined score of "9", "10" or "11"); post-pubertal (a combined score of "12"). The PS score was inserted to equations of Slaughter and colleagues [21] to estimate %BF.

An optical acquisition system (Optojump, Microgate, Udine, Italy) was used to measure the explosive power of the lower extremities of soccer players through a jump test (countermovement jump, CMJ) that showed a high test-retest stability coefficients (range 0.80-0.98) [25]. Players performed a CMJ test according to the protocol described by Bosco *et al.* [26]. Researchers asked to the subjects, from the standing position, to bend quickly their knees to a 90° angle and, immediately after, to perform a maximal vertical thrust (str*etc*h-shortening cycle), with the hands on the hips during the jump to avoid any effect of arm-swing, and trying to avoid any knee or trunk countermovement. During the phase of flight, subjects had to keep their body vertical, and land with knees fully extended. The optical system is triggered by the feet of the subject at the instant of taking-off and at contact upon landing (10^{-3}s of resolution) and the height of jump was calculated in real time by a specific software [27, 28]. Each subject performed three correct jumps and the highest was taken for further analysis. If soccer players failed to adhere to the rigorous protocol, the trial was repeated after an additional one minute rest.

STATISTICAL ANALYSES

Data are reported as means and standard deviations. Before using parametric tests, the assumption of normality was verified using the Shapiro-Wilk test. The internal consistency of PDS questionnaire was determined by calculating Cronbach's α coefficient (Cα). Cα value ranges from 0 (no internal consistency) to 1 (perfect internal consistency) with values equal to or above 0.7 considered sufficiently reliable [29]. Pearson product-moment correlations among variables were calculated considering all subjects, within categories ("Giovanissimi", "Allievi" and "Juniores"), and also within sub-categories ("Giovanissimi: "A", "B" and "C"; Allievi: "A" and "B"). According to Hopkins [30] correlation values were considered trivial (< 0.1), small (from 0.1 to 0.30), moderate (from 0.3 to 0.5), large (from 0.5 to 0.7), very large (from 0.7 to 0.9), nearly perfect (> 0.9), and perfect (1.0), respectively. A step-wise multiple linear regression analysis was used to predict CMJ performance; variables having a significant relationship were included in the analysis. The adjusted R^2 was used to assess the proportion of the variance explained by the independent variables.

Statistics analyses were performed using the statistical package for social sciences IBM SPSS software (ver. 22 version; SPSS Inc., Chicago, IL, USA).

RESULTS

Table **1** reports Means ± standard deviations of CMJ data across categories and sub-categories.

Table 1. Means ± standard deviations of CMJ data across categories and sub-categories.

Category	CMJ (cm)		
	Mean	±	*SD*
Giovanissimi "C"	20.8	±	5.3
Giovanissimi "B"	24.5	±	3.8
Giovanissimi "A"	25.9	±	3.4
Giovanissimi	*23.5*	±	*4.8*
Allievi "B"	29.1	±	4.4
Allievi "A"	28.7	±	5.0
Allievi	*28.9*	±	*4.6*
Juniores	*31.3*	±	*4.5*
Total	26.3	±	5.6

Variables data (Means ± standard deviations) correlated with CMJ are presented in (Table **2**).

Table 2. Variables data correlated with CMJ.

	Category									Total (n=114)		
	Giovanissimi (n=63)			*Allievi (n=33)*			*Juniores (n=18)*					
	Mean	±	*SD*	*Mean*	±	*SD*	*Mean*	±	*SD*	*Mean*	±	*SD*
AGE (month)	147.3	±	11.0	174.5	±	6.7	196.6	±	8.0	**162.4**	±	**20.8**
BMI (kg/m^2)	20.5	±	2.4	21.4	±	2.3	23.2	±	2.4	**21.2**	±	**2.5**
FFM (kg)	45.4	±	8.2	56.0	±	6.0	60.7	±	4.8	**50.7**	±	**9.4**
%BF (%)	16.8	±	6.0	14.0	±	5.2	14.2	±	6.4	**15.6**	±	**5.9**
PDS (AU)	2.2	±	0.6	2.8	±	0.6	3.3	±	0.3	**2.6**	±	**0.7**

Note: AGE = age observed in month CMJ = explosive power (countermovement jump) BMI = Body mass index % BF = percentage of body fat FFM = fat free mass PDS = pubertal development scale

Table **3** reports the number and the frequency distributions (%) for each group of subjects.

Table 3. Frequency distribution e percentuage of distribution (%) of all subjects.

Category	*Subjects*									
	pre-pubertal		*beginning pubertal*		*mid-pubertal*		*advanced pubertal*		*Post-pubertal*	
	N°	*%*	*N°*	*%*	*N°*	*%*	*N°*	*%*	*N°*	*%*
Giovanissimi "C"	1	5	12	55	9	41	0	0	0	0
Giovanissimi "B"	0	0	10	48	8	38	3	14	0	0
Giovanissimi "A"	1	5	0	0	11	55	8	40	0	0
Giovanissimi	*2*	*3*	*22*	*35*	*28*	*44*	*11*	*17*	*0*	*0*
Allievi "B"	0	0	2	13	11	69	3	19	0	0
Allievi "A"	0	0	1	6	6	35	9	53	1	6
Allievi	*0*	*0*	*3*	*9*	*17*	*52*	*12*	*36*	*1*	*2*
Juniores	*0*	*0*	*0*	*0*	*2*	*13*	*13*	*81*	*1*	*6*
Total	***2***	***2***	***25***	***22***	***47***	***42***	***36***	***32***	***2***	***2***

Considering all subjects, we found an excellent internal consistency for PDS questionnaire (0.89). (Table **4**) shows correlation coefficient for youth categories.

Within “Giovanissimi” category, significant correlations were found between chronological age and CMJ (r= 0.45), FFM (r=0.63), and PDS (r=0.56). FFM showed large correlation with PDS (r=0.63) while %BF showed only correlation with BMI (r=0.63).

In “Allievi” category, moderate correlations were observed between chronological age and FFM (r=0.36) and BMI (r=0.37). FFM showed very large (r=0.71) correlation with BMI, and moderate (r= 0.42) with PDS. Further, PDS showed a negative correlation with %BF (r= -0.45) and moderate correlation with CMJ (r= 0.46). In addition, large correlations were observed between %BF and BMI (r=0.59).

In “Juniores” category, a significant correlation were represented only by BMI with FFM (r=0.63) and %BF (r=0.84).

Table 4. Correlation coefficients for youth categories.

Category	Variables	*AGE*	CMJ	FFM	BMI	%BF	PDS
Giovanissimi	*AGE*	1					
	CMJ	0.40**	1				
	FFM	0.68**	0.33**	1			
	BMI	0.09	-0.09	0.41**	1		
	%BF	-0.21	-0.35**	-0.15	0.63**	1	
	PDS	0.56**	0.33**	0.63**	0.19	-0.21	1
	Sub-category	0.94**	0.42**	0.62**	0.11	-0.20	0.55**
Allievi	*AGE*	1					
	CMJ	-0.18	1				
	FFM	0.35*	0.16	1			
	BMI	0.47**	0.03	0.71**	1		
	%BF	0.21	-0.26	0.19	0.59**	1	
	PDS	0.15	0.46**	0.42*	0.16	-0.45**	1
	Sub-category	0.68**	-0.04	0.39*	0.32	0.02	0.18
Juniores	*AGE*	1					
	CMJ	0.06	1				
	FFM	0.18	-0.09	1			
	BMI	-0.27	0.02	0.63*	1		
	%BF	-0.33	-0.24	0.28	0.84**	1	
	PDS	0.19	0.21	0.18	0.3	0.14	1
Total	*AGE*	1.0					
	CMJ	0.57**	1.0				
	FFM	0.78**	0.52**	1.0			
	BMI	0.36**	0.14	0.56**	1.0		
	%BF	-0.25**	-0.36**	-0.16	0.54**	1.0	
	PDS	0.67**	0.55**	0.71**	0.34**	-0.31**	1.0
	Sub-category	0.97**	0.59**	0.77**	0.36**	-0.25**	0.66**

***p*< 0.01 **p*< 0.05 Note: AGE = age observed in month CMJ= explosive power (countermovement jump) BMI = Body mass index % BF = percentage of body fat FFM = fat free mass PDS = pubertal development scale Sub-category = 3 of Giovanissimi (“A”, “B” and “ C”) and 2 of Allievi (“A” and “B”)

The results of the stepwise multiple linear regression analysis for the assessment of the determinants of CMJ performance are presented in (Table **5**). The model with sub-category, PDS, and %BF as predictors explained 41% of the variance of CMJ performance in all subjects. Considering the “Giovanissimi” category, sub-category and %BF as predictors explained 21% of the variance of CMJ performance. In the “Allievi” category the PSD was the only predictor explaining the 18%, of the CMJ performance variance. No significant model to the “Juniors” category was found.

Table 5. Stepwise multiple linear regression analyses for the assessment of determinants of CMJ performance.

Model (subjects)	R	Adj R^2	*p*	Predictors’ coefficients
All	0.653	0.409	<0.001	constant = 20.165 sub-catecory = 1.269 PDS = 1.921 %BF = -0.183
Giovanissimi	0.489	0.213	<0.001	constant = 22.297 sub-category = 2.236 %BF = -0.210
Allievi	0.458	0.184	0.007	constant = 18.229 PDS = 3.848
Juniores	0.236	-0.012	0.383	constant = 33.648 %BF = -0.165

Note: % BF = percentage of body fat PDS = pubertal development scale
Sub-category = 3 of Giovanissimi (“A”, “B” and “ C”) and 2 of Allievi (“A” and “B”)

DISCUSSION

The purpose of this study was to investigate the relationship among PDS, chronological age and CMJ in young soccer players. The main findings of this study were 1) the significant correlations among several variables (FFM, %BF, PDS, Sub-category) and CMJ considering all subjects and significant correlation between PDS and CMJ within "Giovanissimi" and "Allievi" categories and 2) the presence of PDS in the regression equation as predictor of CMJ.

Although other studies [17, 18, 31, 32] have indicated that the relationship between age and physical characteristics was important indicator to identify talented soccer players, few studies have investigated the correlation between chronological age and puberty in young soccer players as useful indicators for training prescription and the quantification of training loads.

Despite in young sport competitions children are divided according to their chronological age, Roemmich and Rogol [33] have shown that significant variation in performance may arise because of differences in growth and physical development between those born early and late in the (selection) year. These age differences can have little relevance for adults but can be significant in children.

Physical and physiological differences between the young and adult athlete may cause children to be more vulnerable to injury [34]. Previous studies showed that young soccer players had a high risk of overuse injuries [35], an incidence of injuries increasing with age [36, 37], a frequency peak of injuries at the age of 15-16 years [38], and previous injury as a high risk factor of re-injuries [39]. A study by Price *et al.* [40] declared that greater attention should be placed to the link between musculoskeletal development and the onset of young related conditions (*i.e.* Osgood-Schlatter's disease), and to the increased rates of injury during preseason training and after the mid- season break. In this way, Armstrong and Welsman [41] stated "children are not mini-adults" indicating that our understanding of the physiological exercise of an adult cannot just be scaled down and applied to children.

The results of this study have shown correlations among variables calculated considering all subjects and also within categories. These results are in agreement with Malina and colleagues [42] that showed as age, body size and maturity status contribute significantly to variation in performance on soccer-specific skill tests. Despite correlations among variables within categories "Giovanissimi" and "Allievi" could be explained by potential influence of different variation in growth velocity, the lack of significant correlation in the "Juniores" could be explained by the higher presence (81%) of "advanced pubertal" in this category than other category.

Given that the care of physical training places a heavy burden on the physiological and psychological responses of athletes [43], particular attention should be placed on the administration of training load. Bunc *et al.* [44] showed that the parameters that characterize the body composition may better reflect the changes in the quality and quantity of the imposed training load and/or training state than the maximal functional variables in soccer players and thus may be used like a supplementary criterion of imposed training effectivity. In fact, high inter-individual variability (pubertal stage, BMI, CMJ, *etc.*) may be found within the same class of athletes selected for chronological age and could determine a considerable difference in performance results.

A number of studies [8, 45] have demonstrated that the countermovement jump is a useful test to functional evaluation of the fitness performance in soccer and it is correlated with maximal muscular strength of jump height performances in professional soccer players. In addition, previous studies [46, 47] have found a large correlation between FFM and CMJ in 7-13 years-old boys and the directly proportional changes in FFM and CMJ in 11-16 years-old. According to Nikolaïdis [48, 49] and Degache and colleagues [50], in this study we have found a significant correlation between age and explosive performance in all subjects. Moreover, results obtained in the multiple regression analysis on all subjects showed that PDS, with sub-categories and %BF, is a useful parameter to predict CMJ (Adj R^2=0.41). Despite in "Giovanissimi" category the sub-categories and the %BF are important variables to predict CMJ (Adj R^2=0.21), the PDS is the only important predictor of CMJ in "Allievi" category (Adj R^2=0.18]. Data do not allow a specific equation for the category "Juniores" because 1) no variables significantly correlated with CMJ and 2) the predictors PDS and FFM showed very similar values between subjects highlighting low heterogeneity.

For these reasons, we agree with Baldari *et al.* [51] who suggested that physical training programs should be administered according to individual biological characteristics and not according to their chronological age. Since chronological age and development rarely progress at the same rate [52], adequate training during puberty is an important factor to the future health development of young soccer players.

In the past decades, the physiological maturational level of children and adolescents were assessed using accurate methods (*i.e.* skeletal, endocrine and somatic changes) with the utilization of sophisticated and expensive equipment. For example, to evaluate the variability of different biological parameters (anthropometry, pubertal stage, hormones, *etc*.) within athletes selected by chronological age in the same class, Di Luigi and colleagues [53] used medical examination, Tanner scale and salivary samples. In that study they observed high inter–individual variability and significant correlations between chronological age, puberty and the steroid hormone responses to physical exercise. Although those methods are considered the gold standard for the maturation assessment, they have a limited applicability on large-scale. Given that the PDS questionnaire has demonstrated high internal consistency and correlation with age, CMJ, FFM and %BF, it can be considered as a viable method to assess the pubertal characteristics. A preliminary study of Perroni *et al.* [19] showed that only two out of thirteen soccer players belonging to "Juniores" category (>17yrs) had actually completed the maturation process. In particular, in Italian amateur soccer championships (>17yrs) sport clubs are compelled to include at least four "young" players classified in relation to the age groups (from 18 to 20 years-old), so that it could be useful to evaluate the PDS in order to reduce cost, to highlight talented soccer players, and to propose an adequate training in youth.

Understandably, the main limitations of this study were: 1) the lack of elite young soccer players as control group of subjects, and 2) a small number of soccer players in each sub-category. For these reasons, further assessments (at least 3 time) to assess difference with elite soccer players and the possibility correlations with training load proposed by coach across the regular season, were recommended to ascertain if Self-Administered Rating Scale for Pubertal Development is an adequate predictor of CMJ in category and sub-category of young soccer players.

CONCLUSION

Since statistical analysis has shown a significant correlations between variables in all subject and within categories, to schedule the training programs we have to consider more the measure of pubertal development than chronological age. PDS is a simple, valid, no cost, and easily accessible method to assess the pubertal characteristics. The use of PDS questionnaire can provide useful information about the maturation of the child athlete that can be useful for the coach to create individual conditioning programs to minimize the risk of an excessive workload associated with possible injuries. In fact, training programs should take into account the needs and the growth problems of young soccer players. On this basis, coach must propose adequate training programs with different prescriptions of training load to ensure the "safe" growth of young soccer players.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

HUMAN AND ANIMAL RIGHTS

No Animals/Humans were used for studies that are base of this research.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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