Power, Linear Speed, and Change-Of-Direction Performance Comparisons Across Three Age Categories of Non-Resistance Trained Individuals
Comparaciones de rendimiento de potencia, velocidad lineal y cambio de dirección en tres categorías de edad de individuos entrenados sin Resistencia

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Abstract. The purpose of present study was to compare lower limb power, linear speed, and change of direction performance in non-resistance trained soccer athletes across three distinct age categories (U15, U17, and U20). Seventy-six male soccer athletes of the same professional club participated in this study [U15 (n=25), U17 (n=20) e U20 (n=31)]. All participants were familiar with the assessments and completed all tests in a single session. Tests were performed at the end of the pre-season in the following sequence: a) squat jump (SJ); b) countermovement vertical jump (CMJ); c) linear sprint test (20-m); and d) change of direction test (COD-test). U20 athletes presented better perfomance than the under-15 and under-17 athletes in the sprint and CMJ (p < 0.001). The U20 athletes performed better than under-17 in COD-test and SJ (p < 0.001). The U17 athletes performed better than under-20 athletes in the COD deficit (p < 0.001). The U17 athletes performed better than under-15 athletes in the COD-test (p < 0.001). No significant differences were observed between the U15 and U17 athletes in sprint, COD deficit, CMJ, and SJ (p > 0.05). No differences were observed between the U20 and U15 athletes in COD deficit and SJ (p > 0.05). These results suggest that older non-resistance trained athletes, with greater chronological maturation, and close to the transitional period to the professional level, presented better performance versus the younger age categories.
Keywords: Power output; Sprint; Change of direction

Resumen. El objetivo del presente estudio fue comparar la potencia de las extremidades inferiores, la velocidad lineal y el rendimiento del cambio de dirección en atletas de fútbol sin entrenamiento de fuerza en tres categorías de edad distintas (U15, U17 y U20). Setenta y seis atletas de fútbol masculino del mismo club profesional participaron en este estudio [U15 (n=25), U17 (n=20) y U20 (n=31)]. Todos los participantes estaban familiarizados con las evaluaciones y completaron todas las pruebas en una sola sesión. Las pruebas se realizaron al final de la pretemporada en la siguiente secuencia: a) sentadilla con salto (SJ); b) salto vertical con contramovimiento (CMJ); c) prueba de sprint lineal (20 m); y d) prueba de cambio de dirección (COD-test). Los atletas sub-20 presentaron mejor rendimiento que los atletas sub-15 y sub-17 en velocidad y CMJ (p < 0,001). Los atletas sub-20 se desempeñaron mejor que los sub-17 en COD-test y SJ (p < 0,001). Los deportistas sub-17 se desempeñaron mejor que los sub-20 en el déficit de DQO (p < 0,001). Los atletas sub-17 se desempeñaron mejor que los atletas sub-15 en la prueba COD (p < 0,001). No se observaron diferencias significativas entre los atletas U15 y U17 en velocidad, déficit de COD, CMJ y SJ (p> 0.05). No se observaron diferencias entre los atletas U20 y U15 en déficit de DQO y SJ (p > 0,05). Estos resultados sugieren que los atletas de mayor edad que no entrenan fuerza, con mayor madurez cronológica y próximos al período de transición al nivel profesional, presentaron mejor desempeño frente a las categorías de menor edad.
Palabras clave: Salida de potencia; Sprint; Cambio de dirección.

Introduction

Modern soccer has several idiosyncrasies that are fundamental for performance in an intermittent activity and involve physical, technical, tactical, anthropometric, psychological, and behavioral demands (Sarmento et al., 2018). The physical qualities (e.g., maximum strength, power output, endurance, and multidirectional speed) required for performance are related to tasks inherent to the sport, such as: acceleration, deceleration, speed of change of direction, repeated sprints, agility, jumps, and dribbling (Stølen et al., 2005; Slimani; Nikolaidis, 2019; Magallanes et al., 2022).

Researchers and coaches use different interventions, evaluation, and monitoring methods, aimed to improve performance in different age categories. (Sarmento et al., 2018; Wing et al., 2020). In this sense, the coaching staff directs efforts to evaluate physical abilities, reduce the risk of injuries, and identify talent in different age categories (Dodd; Newans, 2018; Sarmento et al., 2018). Moreover, an adequate investigation an analysis of basic performance parameters is necessary for long-term specialization process and controlling of the training load.

Previous studies compared physical performance in different age categories. Kobal et al.(2016) evaluated soccer athletes that were resistance trained, from the U17, U20 and professional categories. Jump, linear speed, maximum strength, and endurance tests were performed. Apart from linear speed, which showed no significant difference between groups, the professional athletes had better performance in all tests versus the lower categories. Recently, Loturco et al. (2018a) compared performance between different age categories of soccer athletes (U15, U17, U20, and professional) who were resistance training 2 to 3 times per week. It was found that speed improved with increasing age, but the performance of professional ath-

letes in the change of direction test was slower versus the other categories, which may have been due to the specific soccer training model used by these athletes. In both studies it is possible to identify that in the main variables analyzed, there was a progression of performance according to the age group, that is, chronological maturation.

According to available evidence, the adequate training evaluation along the specialization process is paramount. Training monitoring is essential for structuring adequate physical training interventions. However, it is possible to verify that previous investigations generally involves athletes who are engaged in a systematic resistance training process (Kobal et al., 2016; Loturco et al., 2020a). In this sense, it´s imperative an adequate deliberation of the current training scenario since it´s suggested that a considerable portion of youth soccer training clubs may not have access to a systematic resistance training protocol. Therefore, it is necessary to analyze the behavior of performance indicators throughout the specialization process in a sample of football athletes who are Non-Resistance Trained.These investigations are fundamental for coaches who are responsible for structuring, monitoring, and designing interventions through the process of developing a professional soccer athlete.

Additionally, the results of the present study will provide data on the aspects regarding the athletic performance of youth athletes. These evaluation strategies can be used for stratification in the transitional period between categories, or used by clubs that have the same needs. Therefore, the aim of the present study was to compare lower limb power, linear speed, and change of direction speed among non-resistance trained soccer athletes from different age categories (U15, U17 and U20). The main hypothesis of the present study was that due to maturational factors and training experience, differences between age categories would be evident in physical performance parameters (Abarghoueinejad et al., 2021).

Materials & Methods

This was a cross-sectional study that aimed to compare lower limb power performance, linear speed, and change-of-direction ability, in youth athletes from the U15, U17 and U20 categories of the same soccer club. Athletes were grouped based on their chronological age, respecting the rules and criteria that soccer federations and confederations currently use.

Participants

Seventy-six adolescent male soccer athletes participated in this study. All participants were from the same club from different youth categories and participated in the highest level of competition (Table 1). Athletes were selected for convenience, considering that all belonged to the same club in their respective age categories. All subjects were pre-assessed through the Physical Activity readiness Questionnaire (e.g., PAR-Q).

The inclusion criteria were: (a) belonged to the official team within an age category for the respective club. The exclusion criteria were: (a) presented any disease that could be aggravated with the proposed tests, (b) presented any diagnosed musculoskeletal injury or the presence of pain in any region of the body (c) had used ergogenic substances that could influence the study results and (d) responded positively on any of the PAR-Q questions.

Table 1.
Sample´s characteristics (median and interquartile range) (n = 76)

	U15 (n=25)	U17 (n=20)	U20 (n=31)
Age (years)	14 (1)	16 (1)	19 (2)
Body Mass (Kg)	63.8 (12.6)	68.6 (9.7)	73.1 (13.7)
Height (cm)	169.6 (11.4)	173.2 (13.5)	175.2 (13.5)

Experimental Protocol

Those over 18 years old signed an informed consent form, while those under 18 years old together with their legal guardians, signed an informed consent form before participating in the study in accordance with the Declaration of Helsinki and resolution 466/2012 of the National Health Council for research on humans. This study was analyzed and approved by a Research Ethics Committee (IRB number: CAAE 39925620.9.0000.5257).

To reduce the margin of error in each test, the following strategies were adopted. Athletes were asked to attend the test session properly hydrated. Athletes were instructed not to perform any type of exercise in the 48 hours prior to the testing session. Additionally, athletes were instructed not to ingest any stimulants (e.g., caffeine or alcohol) that could alter the test results. Instructions regarding testing procedures were standardized, explained and demonstrated by an experienced researcher. Athletes used their traditional training clothing and were training shoes adequates for an indoor training environment.

Before testing began, anthropometric measurements (body mass and height) were recorded. All athletes were familiar with performance tests since they were recurrent measures in their team routine. The tests were performed in the following order (see Figure 1): 1- squat jump; 2- countermovement vertical jump; 3- linear sprint test; and 4- change of direction test (COD-test). Prior to testing a standardized warm-up lasting from 10 to 15 minutes was performed.
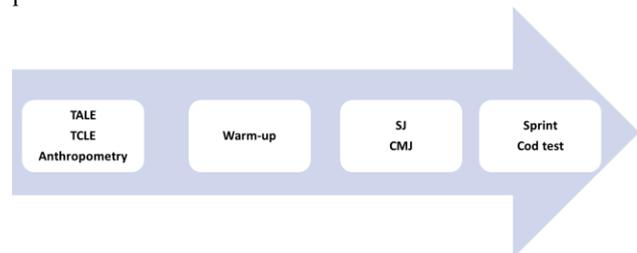

Figure 1. Experimental design: TALE (minor´s informed assent); TCLE (informed consent); CMJ (countermovement jump); COD (change of Direction)

The warm-up consisted of exercises similar to the athlete's daily routine, including bodyweight multiplanar squats, side skipping, dynamic stretching exercises and

short sprints (Ramos et al., 2019). Additionally, the athletes performed three submaximal attempts in each test to complement the warm-up. A 5-minute rest interval was adopted between the warm-up and the start of the test battery. The tests were carried out in the first week before the start of the season at the same day time for all categories. During pre-season athletes had a soccer training frequency of five days a week lasting two hours daily.

Anthropometric Measurements

Height (cm) and body mass (kg) were assessed through a mechanical scale (Filizola model 31, São Paulo, SP, Brazil) attached to a stadiometer.

Vertical Jump Performance

The SJ was performed from an initial static position with 90º knee flexion (determined by goniometer), additionally the athletes were instructed to hold the squat position for two seconds before jumping. For the CMJ, the athletes performed the jumps starting from a standing position with their hands on their hips; then, they flexed their knees using a self-selected depth to avoid altering the natural jumping movement aiming to reach their highest jump. Five attempts were performed at 15-second intervals (Loturco et al., 2018b). Participant's peak power performance was used for statistical analysis. The SJ and CMJ were performed on a force plate with dimensions 600 x 600 x 90 mm and a 600Hz sampling rate (Force plate SV – CEFISE®, Nova Odessa, SP, Brazil) and data were analyzed through a software (version 1.0.3.1, Vertical Jump Power software) synchronized with a notebook.

Linear Speed

Linear speed was assessed through a 20-meter Sprint test in na indoor gymnasium aiming to avoid climatic influences. Distance was established with the use of a measuring tape. Cones were placed at ground zero, this being the starting point, at the 10m point, and at the 20m finish point. In addition, a cone was positioned 5m after the 20m cone to prevent a reduction in speed at the end of the sprint. Athletes were positioned at 0.3 meters before the starting line, and at the evaluator's signal, they ran as fast as possible through the 20-meter course. Each athlete performed three attempts with a three-minute recovery interval to allow for complete recovery between attempts. The fastest trial between the three attempts was used for analysis (Emmonds et al., 2019)

A 240Hz digital video camera (GoPro, Hero 3+ black, GoPro Inc, San Mateo, California, USA) was positioned perpendicular to the performance of the sprint path in the sagittal plane, directed at the 10-meter mark of the running path at a distance of 14 meters to cover the entire 20-meter path (Bond; Willaert; Noonan, 2017). Total travel speed was calculated using Kinovea video analysis software (version 8.8.15). Speed was calculated as the ratio of distance to time and expressed in m/s.

Change-of-direction Speed

The COD-test was carried out in an indoor gym and consisted of four fractions of 5 meters, demarcated by cones at angles of 100º (see Figure 3). Athletes were asked to decelerate and accelerate as fast as possible around each cone. Two attempts were made, with a 5-minute rest interval between attempts. (Nakamura et al., 2016). Starting from a standing position with the front foot placed 0.3-m behind the first pair of timing gates (CEFISE®, Nova Odessa, SP, Brazil). Athletes were asked to complete the test as quickly as possible until crossing the second pair of timing gates. The fastest time from between the two attempts was used for further analysis. (Nakamura et al., 2016). The speed was expressed in m/s. The COD deficit was used to verify the ability of athletes to transfer their performance in linear speed to a task with changing direction. The COD deficit calculation was performed as follows: 20 meter speed - COD test speed (Loturco et al., 2020a). Speed was expressed in m/s. (Figure 2)
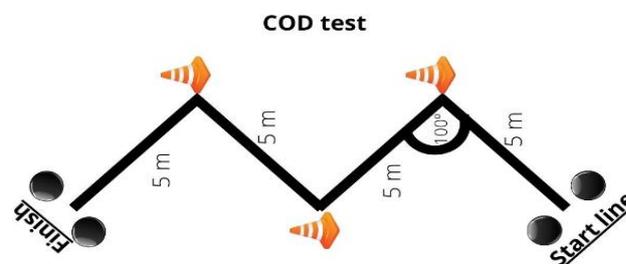

Figure 2. Change of direction Test;Timing gates

Data Analysis

Statistical analysis was performed using SPSS 20.0 (IBM, Armonk, USA). The Shapiro-Wilk normality test was used to asseess data distribution. All of the investigated variables presented non-normal distribution. Thus, data are presented as median and interquartile range. Level of significance was at set 5%.

Kruskall-Wallis test with Dunn's Post-Hoc test was used to compare the variables between the three categories. To analyze the magnitudes of the differences, effect sizes (ES) were calculated using eta-squared (η^2) (Tomczak; Tomczak, 2014) with G-Power 3.1.9.7 (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany). ES were classified according to Hopkins et al.,(2009): Very small: ≤ 0.10; Small: 0.10-0.24; Medium: 0.25-0.39; Large: ≥ 0.40.

Results

Descriptive statistics regarding performance comparisons between categories are displayed on Table 2.

With regard to the 20-meter sprint test, U20 athletes had better performance compared to their younger counterparts ($p < 0.001$). Additionally, there was no significant difference between the U17 and U15 athletes ($p > 0.05$).

Regarding performance in the COD-test, the U20 athletes performed significantly better versus the U17 athletes (p < 0.001), while U17 athletes had greater performance compared to U15 (p < 0.001). In the COD deficit, U17 athletes performed significantly better versus the U20 athletes (p < 0.001). No significant differences were observed between the U17 and U15 athletes, as well as no differences between U20 and U15 athletes (p > 0.05).

Regarding vertical jump performance, it was found that in the CMJ, the under-20 athletes performed significantly better versus the U15 and U17 athletes (p < 0.001); however, no significant differences were found between the U15 and U17 athletes (p > 0.05). In the SJ, significantly higher performance was observed in the U20

athletes versus the U17 athletes (p = 0.023); however, no significant differences were observed between the U15 (p > 0.05) versus the U17 and U20 athletes (p > 0.05).

Effect sizes indicated a large effect for sprint performance of U20 athletes compared to U15, and U17. For COD ability there was a small magnitude of effect for comparisons between U20 and U17, as well as between U17 and U15. Also, considering the cod-deficit, there was a small magnitude of effect between U20 and U17 categories. Regarding CMJ performance, there was a small magnitude of effect when comparing athletes of U20 category to U15 and U17. Lastly, regarding SJ performance there was a small magnitude of effect between U20 and U17 athletes.

Table 2.
Comparisons between performance variables (n = 76)

	U15	U17	U20	P	ES
	MED (IQR) [CI 95%]	MED (IQR) [CI 95%]	MED (IQR) [CI 95%]		
Sprint 20m (m/s)	6.25 (0.69) [6.00 − 6.32]	6.15 (0.33) [5.98 − 6.26]	6.60 (0.26) [6.58 − 6.73]	<0.001¥#	0.52 [large]
COD (m/s)	3.39 (0.59) [3.30 − 3.48]	3.57 (0.27) [3.48 − 3.68]	3.63 (0.36) [3.57 − 3.70]	<0.001*¥	0.23 [small]
COD Deficit (m/s)	2.94 (0.59) [2.62 - 2.91]	2.58 (0.59) [2.36 − 2.71]	3.02 (0.55) [2.90 − 3.13]	<0.001¥	0.23 [small]
CMJ (w)	2521.80 (708.30) [2359.4 − 2721.8]	2886.99 (947.38) [2844.3 − 2886.9]	3063.45 (502.90) [2861.71 − 3236.91]	<0.001¥#	0.22 [small]
SJ (w)	2421.58 (567.45) [2176.0 − 2535.6]	2580.35 (593.10) [2400.5 − 2920.6]	2741.25 (753.85) [2529.6 − 2928.1]	0.023¥	0.10 [very small]

MED – median; IQR – interquartil range; CI – confidence interval; CMJ– countermovement jump; SJ – squat jump; ES- effect size; * - diferences between U15 and U17; ¥ - differences between U17 and U20; # - differences between U15 and U20. (p < 0.05)

Discussion

The purpose of the present study was to compare performance parameters among non-resistance trained soccer athletes from different age categories (U15, U17 and U20). The main results of the present study confirm the established hypothesis, since in relation to the lower categories, the U20 athletes presented superior performance in all tasks, except for the COD deficit. However, the relationship between performance and development was not verified between U15 and U17 athletes, except for the COD test since the performance of U17 athletes was significantly better versus the U15 athletes.

In the sports scenario, it is highly speculated that performance across different categories is related to an individual′s maturational status (chronological or biological). However, a deep analysis of the available scientific evidence is fundamental for future interventions and testing procedures. When analyzing lower limb power performance, Tavares et al., (2017) investigated 69 strength-trained soccer athletes of U17, U19, and professional categories. Their results suggested no diferences in power performance of U17 and U19 categories. On the other hand, professional athletes presented better performance compared to younger categories. Still, Nikolaidis (2014), evaluated CMJ in a sample composed of 275 U10 and professional soccer athletes. The results showed improvements on CMJ performance throughout the specialization process, that is, athletes with higher chronological age had

greater indexes than their younger counterparts in all of the proposed comparisons. Nevertheless, it was not informed if participants regularly practiced resistance training (RT). These results corroborated the investigation conducted by Loturco et al.(11), who compared the performance of soccer athletes (U15, U17 and U20) who were involved in RT in the CMJ and SJ. The results suggested a relationship between performance and chronological development. Although the maturational process is an important factor for performance, it should be emphasized that in the athletes' training routine, the weekly RT volume was programmed according to each category. That is, athletes of higher categories had greater training frequency and availability. In view of the previously cited studies, it is clear that in the presence of resistance training, the performance of individuals advances according to chronological advancement.

However in the present investigation, the results partially conflicted with the previously cited research since U20 athletes presented superior performance in the CMJ compared to both U15 and U17 categories while on SJ this superiority was only verified between U20 and U17 athletes. Thus, the performance/maturation relationship was not established in all comparisons between categories. That way, the fact that the athletes of the present sample were not resistance-trained may be a relevant factor for these discrepancies between studies since power depends on an athlete′s ability to produce force. (Bedoya et al., 2015). It′s worth to highlight that, even in the absence of

RT, the U20 athletes performed better versus the other categories. In fact, the U20 athletes had more years of experience and exposure to training, which is related to higher levels of strength and power (Slimani; Nikolaidis, 2019).

Linear speed and change of direction speed are fundamental for the performance of young soccer athletes and, given this fact, coaches and other professionals involved carry out assessments and seek methods to optimize these physical abilities linked to speed. The results of the present study showed that in the 20-m sprint, the U20 athletes were faster than the U15 and U17 athletes; however, there was no difference between the U15 and U17 athletes. These results were partially consistent with Loturco et al. (2018b), who reported significantly better sprint performance in the U20 athletes versus the U15 and U17 athletes, as it was also reported that the U17 athletes were significantly faster than the U15 athletes. As previously mentioned, Loturco et al. (2018b), evaluated athletes who were resistance-trained with adequate manipulation of training variables linked to frequency and volume that were diferente between categories and this information can´t be disregarded. Additionally, the small age gap between U15 na U17 and the participant's training experience probably did not suffer any maturational influence that would affect an individual´s performance, especially in a scenario where both categories did not participate in regular RT programs.

It´s suggested that genetics, muscle fiber type and glycolytic capacity should be considered as factors that influence sprint performance. (Moya et al., 2021; Metaxas et al., 2019; Ratel e Duché e Williams, 2006). It´s importante to highlight that sprint performance is associated to maximum strength, (Peñailillo et al., 2016; Silva; Nassis; Rebelo, 2015), power (Randell et al., 2010) and running technique (Haugen; Mcghie; Ettema, 2019), thus, it´s interesting to reflect on the influence of RT, technical, and coordenative sprint exercises on training transfer and consequently performance.

Change of direction speed is often used in test batteries for the evaluation of soccer athletes and talent screening (Dodd; Newans, 2018). In the present study, change of direction performance showed significant differences, suggesting a relationship of improvement throughout the specialization process, that is, U20 athletes were faster than U17, and U17 athletes faster than U15 athletes. These results diverged from Loturco et al. (2020), which compared the performance of 182 soccer athletes from different categories (U15, U17, U20 and professional) that were resistance trained. According to the results, no significant differences were observed between athletes from U15, U17 and U20 categories. Change of direction performance is multifactorial (Dos'Santos et al., 2018; Nimphius et al., 2018), Therefore, training characteristics may be preponderant for the differences in the results described above. That said, it is possible that the higher level of experience for the U20 athletes was the reason for superior results. Regarding the COD deficit, we found a small difference between U20 athletes and U17. Interestingly, U17 athletes had a smaller deficit than U20 athletes suggesting that U17 athletes demonstrated a better ability to take advantage of the COD moment. Such discrepancy may be associated to kinetic and kinematic elements that were not evaluated in the present study, as well as the specificity of the training carried out in the different categories, since soccer players, at the end of the specialization process, usually have a training routine (technical, tactical and physical) and schedule different from the other categories. The results presented by Loturco et al.(2020) reported an augment in COD deficit throughout the specialization process. According to the authors, These alterations can be justified by some failures in the RT performed by their sample and in the specific interventions of the modality. RT´s effect on COD performed was previously reported by Chaabene et al. (2020), advocating that RT positively interferes with the speed in COD tasks in young athletes, regardless of the frequency and volume of training sessions.

It is crucial to reflect on the possible combined influence of these factors with the use of resistance training, drills, and other coordinative strategies and their effects on performance indicators with volume and frequency corresponding to an athlete's needs and capability of athletes from different categories. Wing et al. (2020) reinforces the influence of RT, reporting that performance indicators of young soccer athletes are related to strength and power levels.

This study presents limitations, such as the lack of maturational assessment of the athletes and field assessment aiming at the ecological validity of the investigation. Due to these limitations, we suggest caution in using the results. The authors also highlight the need for future studies with a larger sample size and additional analyses to verify the association between physical performance indicators in athletes with this training profile.

It´s suggested that future research be conducted to compare soccer athletes of distinct age categories who regularly practice RT and who do not practice RT to verify RT´s influence on performance indicators. Additionally, some gaps related to the association between performance indicators evaluated in the present study remain unclear regarding soccer players who do not practice RT. This information can help professionals during long-term training, monitoring, and evaluation of athletes since it is unclear whether most football clubs have the physical and financial structure to support high-level training.

Conclusion

According to the results of the present study, we can conclude that the specialization process is a relevant factor for performance among basic categories in which the RT does not compose the physical conditioning program of the athletes, especially when we compare the younger

athletes to the others who are closer to the transition to professional soccer.

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