

## Acceleration and Speed Performance of Brazilian Elite Soccer Players of Different Age-Categories

by

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*This study aimed to compare vertical jump ability (squat-jump [SJ] and countermovement-jump [CMJ]), relative to body mass mean propulsive power in the jump-squat (MPP-REL JS), and the 0-5, 5-10, and 10-20 m acceleration and speed among soccer players from the same professional club, divided into age-categories (U15 [n = 20], U17 [n = 53], U20 [n = 22] and senior [n = 25] players). The tests were performed at the start of the preseason in indoor facilities. The magnitude-based inference approach and the standardized differences (based on effect sizes) were used to compare the age-groups. The SJ, CMJ, and MPP-REL JS increased across the age-groups up to U20, the latter being similar to senior players. Interestingly, the 0-5 m acceleration was likely and possibly higher in U15 players compared to U17 and senior players. Although soccer athletes improve their unloaded and loaded jump abilities across the age-categories (plateauing during adulthood), the same does not hold true for acceleration capacity, from the early phases of players' development (i.e., U15). Strength and conditioning professionals should seek effective strategies to minimize impairment in maximal acceleration performance of elite soccer players throughout their prospective training programs.*

**Key words:** soccer, speed, muscle power, youth players, team sports.

### Introduction

Successful participation in professional soccer matches requires progressively faster and more powerful players. For instance, it has recently been shown that, across the 2006-2007 and 2012-2013 Premier League seasons, the number of sprints ( $31 \pm 14$  vs.  $57 \pm 20$ ), especially the explosive ones (i.e., entry into the sprint zone with no excursion into the high-speed zone in the previous 0.5 s period), along with the maximal running speed ( $9.12 \pm 0.43$  to  $9.55 \pm 0.40$  m·s<sup>-1</sup>), increased progressively year by year (Barnes et al., 2014). In addition, goal scoring opportunities are frequently created by explosive activities such

as short straight sprints (Faude et al., 2012). Therefore, improving players' game-related effectiveness implies optimizing the physical factors related to the ability to sprint fast (Loturco et al., 2016b).

It is known, for example, that sprinting speed is highly associated with performance achieved in vertical unloaded and loaded jumps (Loturco et al., 2015a, d). For this reason, interventional studies in soccer have aimed at improving soccer players' sprinting speed using plyometrics and jump squat (JS) training strategies (Loturco et al., 2015e, f). For instance,

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gains in jumping ability were positively transferred to sprinting speed in U20 elite soccer players (Loturco et al., 2015f). However, less is known about the age-related elements of these factors and how power-speed characteristics change as a player develops through age-group classifications (i.e., U15 players) into adult categories (i.e., senior players) in professional clubs. This is important in order to provide guidelines on expected longitudinal gains (Williams et al., 2011) and to enable a coach to tailor the choice of training strategies appropriately. It is expected that, across age-categories, the improvement in lower limb power, as evaluated by unloaded and loaded jumps, will be accompanied by positive changes in sprinting speed.

To date, a very interesting study conducted by Williams et al. (2011) demonstrated that the 30-m sprint time improved by a rate of 2.7% per year and jump height by a rate of 6.9% per year in male soccer players aged 12 to 16 taking part in an English youth academy. The linear cumulative changes occurring in the investigated age span were attributed to increased muscle mass, changes in muscle-tendon architecture, and improved neural control and coordination (Williams et al., 2011). Nevertheless, little details are provided as to how much of this change was due to maturational aspects and how much due to training induced adaptations. The results of Spencer et al. (2011) suggest that sprint speed increases linearly across U11 to U18 categories. On the other hand, countermovement jump (CMJ) height and 15-m sprint speed were not different between senior ( $\approx 24$  yrs) and junior ( $\approx 18$  yrs) elite male players (Mujika et al., 2009b). Interestingly, senior futsal players ( $\approx 28$  yrs) presented worse sprint performance and lower mean propulsive power in the JS exercise (MPP JS) than their U20 peers (Nakamura et al., 2016), but again little discussion was presented on training activities, which are important in the development of speed and power abilities. In this sense, it is possible that in adulthood, some neuromechanical capacities can be stabilized or partially lost and that this period does not necessarily result in an increase in these capacities. In fact, there are multiple factors that can potentially explain this, such as the quantity and type of training aimed at enhancing

neuromuscular performance, the effects of prolonged exposure to concurrent training (i.e., high-volume of technical and tactical training in detriment to neuromuscular training), and the end of the maturational development (Nakamura et al., 2016; Noon et al., 2015; Gołaś et al., 2016). Thus, a more thorough analysis of possible age-category neuromuscular differences in a representative sample of highly selected players is necessary to identify critical “stages” of power-speed development in elite soccer cohorts. Certainly, the investigation of these aspects may provide useful insights for creating optimal training strategies to gradually improve physical performance of these team-sport athletes throughout their prospective development.

The aim of this study was to examine the possible differences in power-speed characteristics of elite soccer players who were part of the same professional team, but divided into the U15, U17, U20 and senior age-categories. Our working hypothesis was that performance in the unloaded and loaded vertical jump tests, and in the sprinting speed test, would be improved across the younger age-categories, but that performance in all tests would not be different between the U20 and senior players (Meylan et al., 2014).

## Methods

### Study Design

The current study is a cross-sectional comparative study aimed at detecting possible differences in power-speed characteristics among four different official age-categories of soccer players (U15, U17, U20 and senior athletes) from the same professional Brazilian soccer club. Similarly to previous studies (Deprez et al., 2015b; Mendez-Villanueva et al., 2011;), players were grouped according to their chronological age rather than according to their biological maturation as soccer federation rules regulate competitions using the former criteria.

### Participants

One-hundred twenty soccer players from four different age-categories (U15:  $n = 20$ ;  $14.2 \pm 0.6$  years;  $62.6 \pm 8.4$  kg;  $174.1 \pm 7.8$  cm; U17:  $n = 53$ ;  $16.2 \pm 0.4$  years;  $67.3 \pm 8.3$  kg;  $177.5 \pm 7.4$  cm; U20:  $n = 22$ ;  $18.1 \pm 0.8$  years;  $71.6 \pm 9.2$  kg;  $177.3 \pm 9.2$  cm; Senior:  $n = 25$ ;  $23.1 \pm 3.8$  years;  $77.6 \pm 7.9$  kg;  $179.0 \pm 6.8$  cm) participated in this study. All

participants were members of the same soccer club and were undertaking different training routines, as planned by the technical staff for each age category (Table 1). Publication of the data related to training content of all age-categories was approved by the technical staff. All tests were performed during the start of the preseason period for all age categories, after a regular off-season period (4 weeks). The study was approved by the Bandeirante Anhanguera University Ethics Committee and all subjects and their legal guardians (when necessary) were informed of the inherent risks and benefits associated with study participation, before signing informed consent forms.

#### **Testing procedures**

Due to the training and assessment routines in the investigated club, all soccer players taking part in this study were already familiar with the testing procedures. The order of the assessments was as follows (with 30-min rest in-between): 1) squat jump (SJ) and CMJ tests; 2) sprinting speed test and; 3) MPP JS. Prior to the tests, the athletes performed standardized warm-up protocols including general (i.e., running at a moderate pace for 5-min followed by active lower limb stretching for 3-min) and specific exercises (submaximal attempts of tested exercises). The warm-up was followed by a 3-min interval, after which the players were required to execute the actual tests.

#### **Mean propulsive power in jump squat exercise**

The MPP JS was assessed on a Smith machine (Hammer Strength, Rosemont, USA). The soccer players were instructed to execute 3 repetitions at maximal velocity for each load, starting at 40% of their body mass (BM). The athletes executed knee flexion until the thigh was parallel to the ground and, after a command, jumped as high as possible, without their shoulder losing contact with the bar. A load of 10% of BM was gradually added in each set until a decrease in mean propulsive power was observed. A 5-min interval was provided between sets. To determine mean propulsive power, a linear transducer (T-Force, Dynamic Measurement System; Ergotech Consulting S.L., Murcia, Spain) was attached to the Smith machine bar. The bar position data were sampled at 1,000 Hz using a computer. The technical specification of the MPP analysis, its calculation and validity,

and the respective validity of the equipment used to perform this measurement have been extensively reported in the literature (Garnacho-Castano et al., 2015; Loturco et al., 2015c). The finite differentiation technique was used to calculate bar velocity and acceleration. We considered the maximum MPP value obtained for data analysis purposes. In order to avoid misinterpretation of the power outputs and considering the differences in BM among the different age categories, we normalized these values by dividing the absolute power value by BM (i.e., relative power =  $W \cdot kg^{-1}$  [MPP REL JS]).

#### **Vertical jumping ability**

Vertical jumping ability was assessed using the SJ and CMJ. In the SJ, a static position with a 90° knee flexion angle was maintained for 2 s before a jump attempt without any preparatory movement. In the CMJ, the soccer players were instructed to perform a downward movement followed by a complete extension of the lower limbs and freely determine the amplitude of the countermovement to avoid changes in the jumping coordination pattern (Mandic et al., 2015). All jumps were executed with the hands on the hips. Five attempts at each jump were performed interspersed by 15-s intervals. The jumps were performed on a contact platform (Smart Jump; Fusion Sport, Coopers Plains, Australia) with the obtained flight time (t) being used to estimate the height of the rise of the body's center of gravity (h) during the vertical jump (i.e.,  $h = gt^2/8$ , where  $g = 9.81 \text{ m} \cdot \text{s}^{-2}$ ). A given jump would be considered valid for analysis if the take-off and landing positions were visually similar. The best attempt was used for data analysis purposes.

#### **Sprinting and acceleration abilities**

Prior to the execution of the speed tests, four pairs of photocells (Smart Speed, Fusion Equipment, AUS) were positioned at distances of 0, 5, 10 and 20 m along the course. The soccer players sprinted twice, starting from a standing position 0.3 m behind the start line. In order to avoid weather influences, the sprint tests were performed on an indoor running track. Sprint velocity (VEL) was calculated as the distance traveled over a measured time interval. The acceleration (ACC) capacity in the different distances (i.e., 0-5, 5-10, and 10-20 m) was calculated as the rate of change of velocity with

respect to time. A 5-min rest interval was allowed between the two attempts and the fastest time was retained for the analyses.

### Statistical analysis

The normality of the data was checked using the Kolmogorov-Smirnov test. Due to the normal distribution, data were described as mean and standard deviation (SD). Magnitude-based inference (Batterham and Hopkins, 2006) was used to compare the differences in the physical test results among the different age categories. The quantitative chances of finding differences in the variables tested were assessed qualitatively as follows: <1%, almost certainly not; 1 to 5%, very unlikely; 5 to 25%, unlikely; 25 to 75%, possible; 75 to 95%, likely; 95 to 99%, very likely; >99%, almost certain. If the chances of having better and poorer results were both >5%, the true difference was rated as unclear. The standardized differences for the comparisons in all variables were analysed using the Cohen's *d* effect size (ES). The magnitude of the ESs was qualitatively interpreted using the following thresholds: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large and; >4.0, nearly perfect (Hopkins et al., 2009).

## Results

Figure 1 shows the unloaded (SJ and CMJ) and loaded (MPP REL JS) vertical jump performances in the different age categories. In the SJ performance, U15 players were *almost certainly* lower than the other categories (ES = 1.02, 1.40, and 1.30 in comparison to U17, U20, and senior, respectively), while U17 were *possibly* lower than U20 and senior players (ES = 0.33 and 0.24, respectively) (Figure 1A). The comparison between U20 and senior players for the SJ was rated as *unclear* (ES = 0.09). In the CMJ, the U15 demonstrated *almost certainly* lower jump height than the other age categories (ES = 1.30, 1.79, and 1.67 in comparison to U17, U20, and senior, respectively). In addition, U17 were *likely* and *possibly* lower in the CMJ height than U20 (ES = 0.41) and senior (ES = 0.31) players, respectively (Figure 1B). The comparison between U20 and senior players for CMJ performance was rated as *unclear* (ES = 0.10).

The absolute MPP JS was *almost certainly* higher in senior players in comparison to the U15 and U17 age categories (ES = 2.57 and 1.74,

respectively) and was *likely* higher than the U20 (ES = 0.60). In addition, the MPP JS in U20 players was *almost certainly* higher than in U15 and U17 age categories (ES = 1.85 and 1.04, respectively), while it was *very likely* higher in the U17 in comparison to the U15 (ES = 0.81). In relation to the MPP REL JS, U15 players demonstrated *very likely* to *almost certainly* differences when compared to the other age categories (ES = 0.62, 1.38, and 1.36 in comparison to U17, U20, and senior, respectively), while U17 presented a *very likely* lower MPP REL JS than U20 (ES = 1.03) and senior (ES = 1.01) soccer players (Figure 1C). The comparison between U20 and senior players for the MPP REL JS was rated as *unclear* (ES = 0.01).

Figure 2 depicts the comparisons of the sprint velocity (VEL) in 5, 10, and 20 m among the different age categories. The VEL 5 m was *likely* lower in the U17 when compared to the other age-categories (ES = 0.42, 0.48, and 0.39, in comparison to U15, U20 and senior, respectively) (Figure 2A). The other pairwise comparisons among the different age-categories for the VEL 5 m were all rated as *unclear* (ES ranging from 0.07 to 0.18). In relation to VEL 10 m, senior players demonstrated *possibly* and *likely* higher values than U15 (ES = 0.28) and U17 (ES = 0.40) categories, respectively, while U20 showed a *possibly* higher VEL 10 m than U17 players (ES = 0.23) (Figure 2B). The other comparisons of the VEL 10 m among the different age categories were all rated as *unclear* (ES ranging from 0.01 to 0.16). In the VEL 20 m, U20 and senior players were *likely* higher than the U15 (ES = 0.47 and 0.45, respectively) and *possibly* higher than the U17 players (ES = 0.31 and 0.29, respectively), while the U17 was *possibly* higher than the U15 age category (ES = 0.24) (Figure 2C). Finally, the comparison between U20 and senior players for the VEL 20 m was rated as *unclear* (ES = 0.02).

Figure 3 shows the comparisons of the ACC between 0-5, 5-10, and 10-20 m among the different age categories. In the ACC 0-5 m, U17 players were *likely* lower than the other age categories (ES = 0.44, 0.49 and 0.39 in comparison to U15, U20, and senior, respectively), while U15 were *possibly* higher than senior players (ES = 0.20) (Figure 3A). The comparison between U15 and U20 as well as between U20 and senior players for the ACC 0-5 m were rated as *unclear* (ES = 0.14 and 0.10, respectively). The U15 players

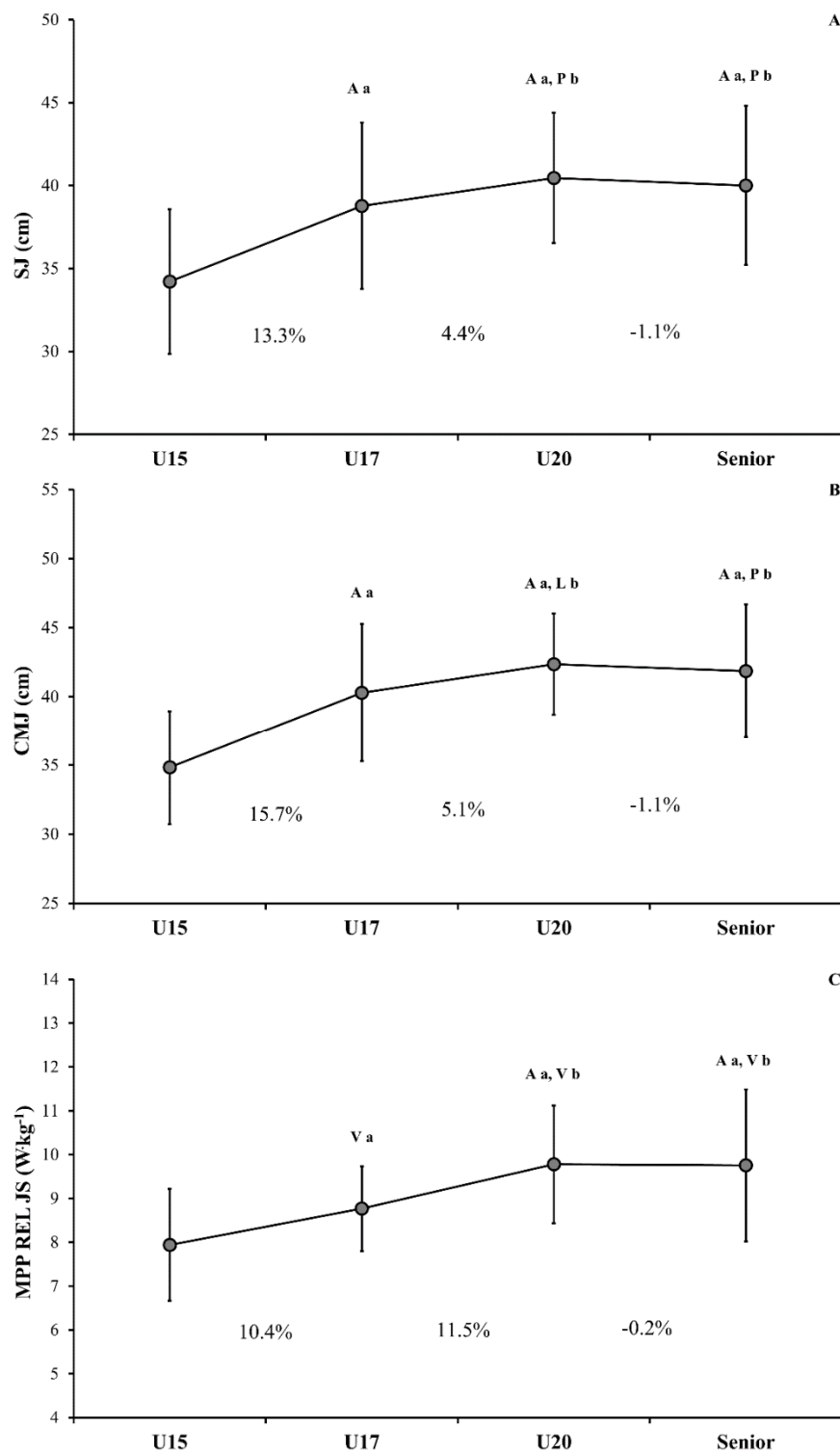
demonstrated an *almost certainly* lower ACC 5-10 m than the other age categories (ES = 1.30, 1.15, and 1.49 in comparison to U17, U20, and senior, respectively). Senior players presented a *possibly* higher ACC 5-10 m than U17 (ES = 0.20) and U20 (ES = 0.31) (Figure 3B). The difference in the ACC 5-10 m between U17 and U20 age categories was rated as *unclear* (ES = 0.16). Finally, the U15

players were *almost certainly* lower in the ACC 10-20 m than the other age categories (ES = 0.96, 1.36, and 0.84 in comparison to U17, U20 and senior, respectively). The ACC 10-20 was *likely* higher in the U20 in comparison to U17 (ES = 0.30) and senior players (ES = 0.39) (Figure 3C). The difference between U17 and senior players for the ACC 10-20 m was rated as *unclear* (ES = 0.12).

**Table 1**  
*Typical weekly training schedule for the different age-categories.*

Category	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
U15	Tec/Tac 60'	Tec/Tac 40' S/PT 30'	Tec/Tac 70'	Tec/Tac 40' S/PT 30'	Tec/Tac 60'	FM 80'
U17	Tec/Tac 60' S/PT 30'	Tec/Tac 70'	Tec/Tac 80' S/PT 30'	Tec/Tac 60'	Tec/Tac 60' S/PT 30'	FM 80'
U20	Tec/Tac 80' S/PT 40'	Tec/Tac 60'	Tec/Tac 70' S/PT 40'	Tec/Tac 90'	Tec/Tac 60' S/PT 40'	FM 90'
Senior	Tec/Tac 90' S/PT 45'	Tec/Tac 120'	Tec/Tac 80' S/PT 45'	Tec/Tac 100'	Tec/Tac 70' S/PT 45'	FM 110'

*Tec/Tac: technical and tactical training based on specific technical actions (e.g., goal shooting, corner kick situations) and small-sided games; S/PT: strength and power training based on general exercises (half-squats, jump squats and leg curls), plyometrics and core training; FM: friendly match.*

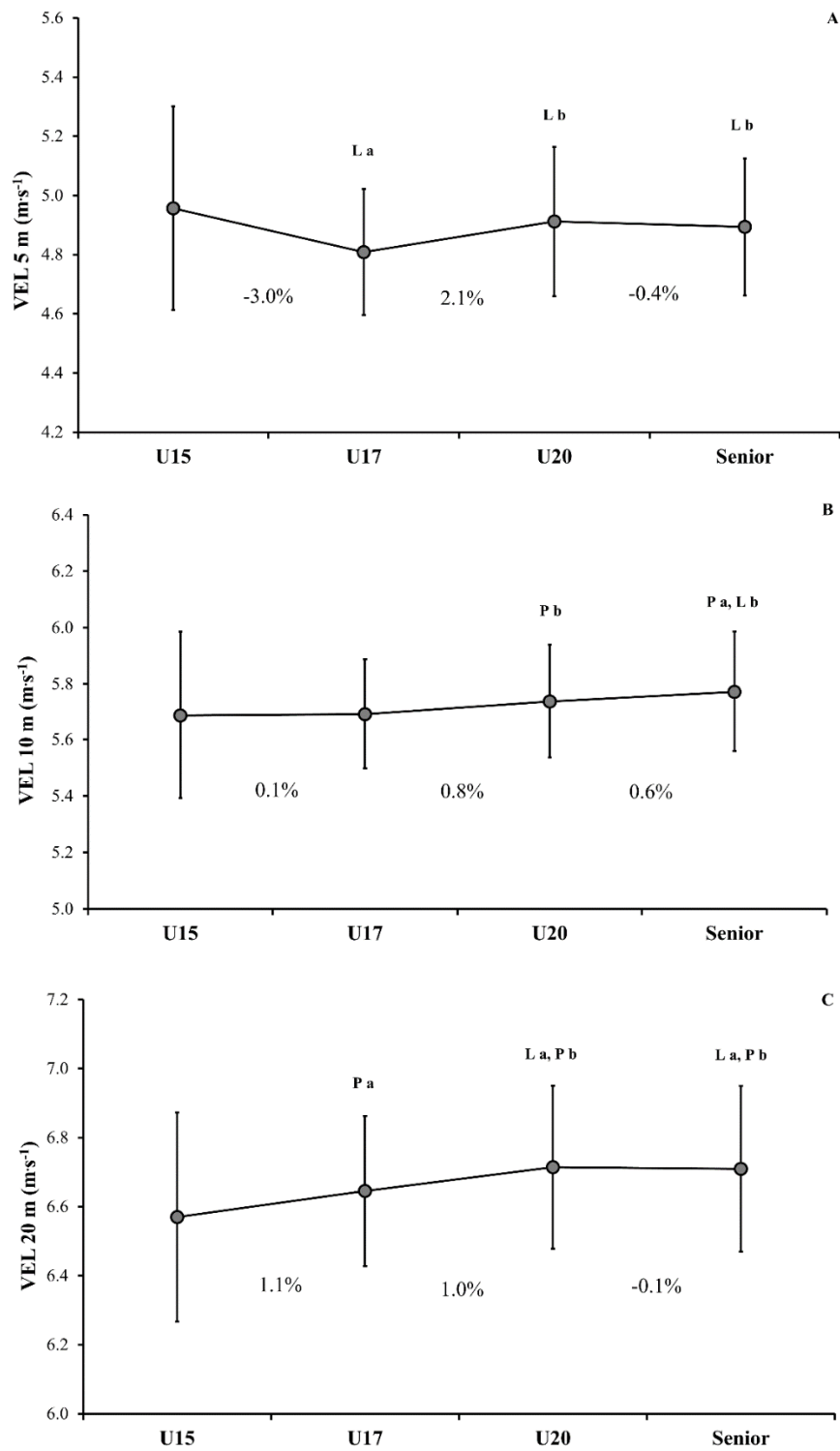


**Figure 1**

*Comparisons of unloaded (SJ and CMJ) and loaded (MPP REL JS)*

*vertical jump performances among the different age-categories of soccer players.*

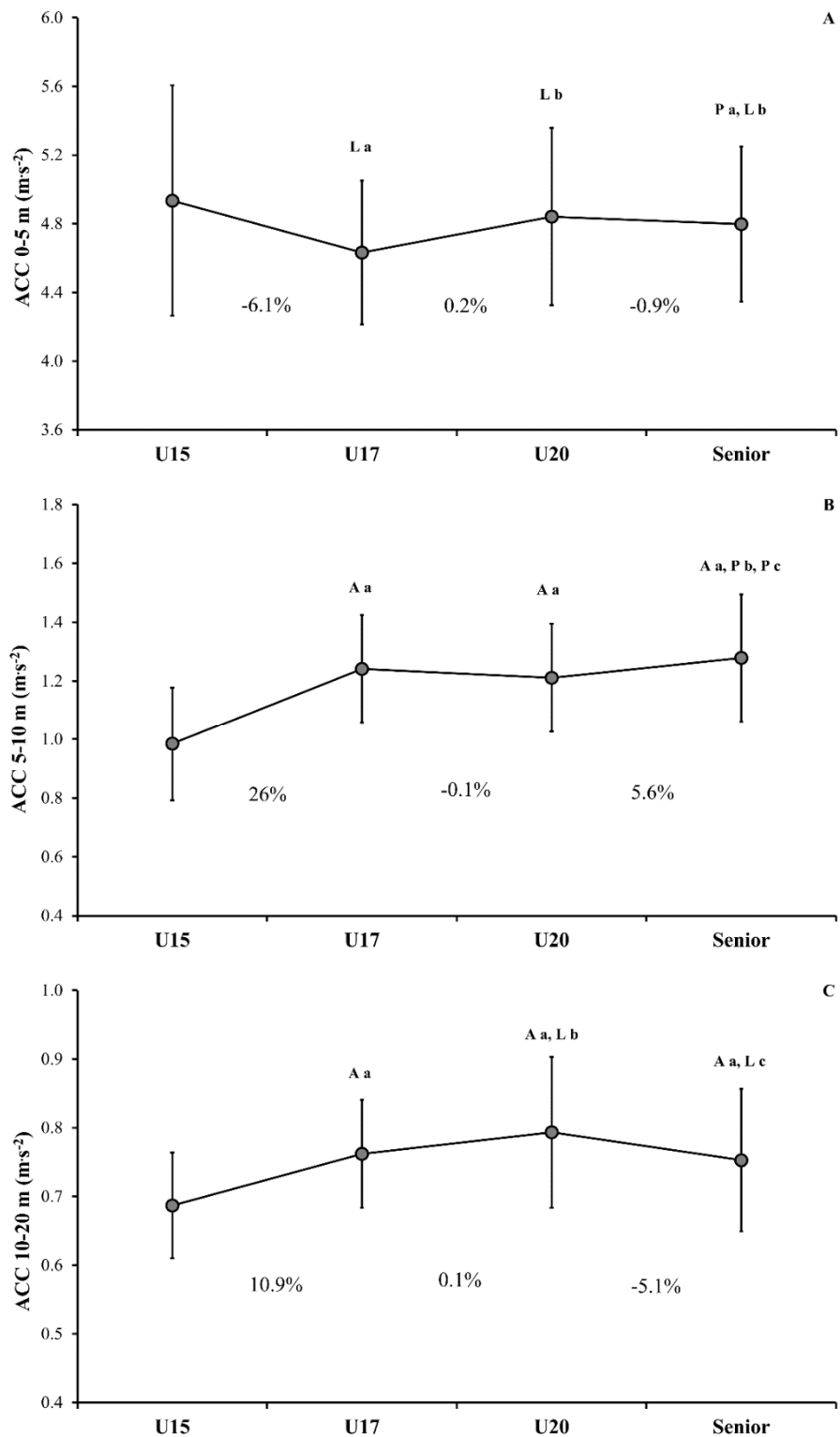
*P: possible difference; L: likely difference V: very likely difference; A: almost certainly difference. Letters a, b, and c correspond to differences from U15, U17, and U20 age-categories, respectively.*



**Figure 2**

*Comparisons of the velocity (VEL) in 5, 10, and 20 m among the different age-categories of soccer players.*

*P: possible difference; L: likely difference. Letters a, b, and c correspond to differences from U15, U17, and U20 age-categories, respectively.*



**Figure 3**

Comparisons of the acceleration (ACC) in 0-5, 5-10, and 10-20 m among the different age-categories of soccer players. L: likely difference; A: almost certainly difference. Letters a, b, and c correspond to differences from U15, U17, and U20 age-categories, respectively.



## Discussion

In this study, we examined the differences in physical performance of elite soccer athletes, who played in four distinct age-categories (i.e., U15, U17, U20 and senior) of the same soccer club. From a general perspective, as expected, throughout the prospective development of these players, the power-related capacities (i.e., jumping ability and muscle power) increased progressively across the ages. On the other hand, although these athletes performed specific strength-power training programs in accordance with their respective ages and necessities, surprisingly, the younger players (i.e., U15) were faster than all the other groups in very-short distances (i.e., 0-5 m). This is the first study to show this important impairment in maximal acceleration performance in the early phases of the development program of the investigated cohort of athletes.

Recently, a series of studies has been developed to investigate changes in neuromuscular performance which occur during the prospective development of soccer athletes. For instance, Loturco et al. (2014) reported that some neuromechanical variables (i.e., absolute muscle power, squat and countermovement jumps) might improve during the transition from the end of adolescence to the mature phase. However, due to the absence of differences in relative muscle power (i.e., W/kg) and sprint capacity over very-short distances (i.e., 0-5 m) between U20 and senior players, the authors highlighted the necessity of increasing the frequency and volume of strength-power training, and the introduction of speed specific training during adulthood. Similarly, Mujika et al. (2009b) observed that performance in some neuromuscular tasks such as vertical jumps and maximal sprints did not differ between elite senior ( $23.8 \pm 3.4$  years) and elite junior players ( $18.4 \pm 0.9$  years), which is strictly in line with our findings. Actually, this lack of improvement in speed ability throughout the soccer age categories seems to be an important contradiction in sport science, due to the increased speed demand in contemporary soccer (Barnes et al., 2014; Faude et al., 2012).

The reasons behind this noteworthy training paradox may be related to two different factors: the interference phenomenon caused by the progressive increase in the volume of typical

soccer training (i.e., technical-tactical training) which normally occurs from younger to older categories (Abade et al., 2014; Coutinho et al., 2015; Docherty and Sporer, 2000), and the ineffectiveness of the neuromuscular training strategies applied to senior players (Kraemer et al., 2004). In fact, several authors have reported the inherent difficulties involved in maximizing speed and power abilities in elite soccer (Loturco et al., 2015e; Silva et al., 2016). In this sense, although we observed worthwhile increases in relative muscle power during the players' maturation (Figure 1), the evolution of speed performance seemed to be very inconsistent. For instance, whereas we noticed meaningful physical improvements from U17 to U20, we detected an unexpected lack of speed enhancements between U20 and senior players. Accordingly, likely impairment in ACC 10-20 m (-5.1%) was reported between these categories, thus revealing that seniors presented compromised capacity to continuously accelerate over longer distances (and, therefore, over "faster speeds"). Furthermore, during this prospective period, an absence of positive responses was also noticed in the unloaded vertical jump performance (i.e., SJ and CMJ), which may partially explain (and connect) these specific neuromechanical factors. Indeed, it has previously been reported that the transition from lower to higher sprint velocities results in shorter contact times with a simultaneous and substantial increase in vertical peak force (Loturco et al., 2015f; Nilsson and Thorstensson, 1989). Thus, athletes capable of applying higher levels of force against the ground in the vertical direction should be equally effective in jumping higher and accelerating for longer than their weaker peers (Loturco et al., 2015d, f). Since our players did not present any improvement in vertical jump ability from the U20 to senior category – even presenting a decrease of 1.1% (rated as unclear) in this specific capacity – it would be reasonable to expect some similar impairment in mechanical factors more associated with high-speed performance.

Surprisingly, the youngest and (theoretically) less specialized players (i.e., U15) were faster at shorter distances (ACC 0-5 m) than all other categories (Figure 3A). From an applied standpoint, this is particularly problematic, given the crucial importance of "shorter sprints" in elite

soccer (Barnes et al., 2014). More recently, Barnes et al. (2014) reported that, across a 7-season period in the English Premier League (i.e., 2006-2013), the mean sprint distance decreased from  $6.9 \pm 1.3$  m to  $5.9 \pm 0.8$  m with the proportion of short-explosive sprints increasing from  $34 \pm 11\%$  to  $47 \pm 9\%$ . Thus, to cope with this increased demand in professional soccer, it is highly recommended that players progressively enhance their maximum acceleration capacity throughout the age categories, achieving their higher levels of performance at senior stages. This “specific neuromuscular preparation” could be important not only for better performance during the matches (Di Salvo et al., 2009), but also to reduce the muscle injury propensity, which is commonly associated with maximal running speeds (Ekstrand et al., 2011; Junge and Dvorak, 2013). As aforementioned, in addition to the interference effects of the typical soccer drills on players’ performance (Dudley and Djamil, 1985; Loturco et al., 2015e), it is possible that the physical training strategies implemented by coaches (and technical staff) during the prospective development of soccer athletes fail to provide an adequate training stimulus to properly (and gradually) develop their speed-related abilities.

Indeed, some authors have suggested that the low percentage of total training time dedicated to strength and power development, and especially dedicated to speed development may be considered as a partial explanation for the absence of significant improvements in sprinting speed in professional soccer (Jeffreys, 2013; Loturco et al., 2015e; Silva et al., 2016). Accordingly, Jones et al. (2013) confirmed that high frequencies of endurance training could potentially increase the magnitude of the interference responses in neuromuscular performance. However, considering that in top-level soccer it is almost impossible to significantly reduce the volume of “typical aerobic loads” in any age category, it can be inferred that the adoption of novel (and more frequent) strength-power and speed training practices is the only adequate alternative to efficiently develop speed-related abilities in elite players. For instance, it was recently reported that the implementation of training schemes based on the optimum power loads could be superior to traditional strength training for eliciting positive adaptations in sprint

performance of professional soccer athletes (Loturco et al., 2016a). As such, the regular use of loaded and unloaded jumps during different training phases (i.e., preseasons and competitive periods) seems to be an alternative and effective strategy for increasing the speed capacity of soccer players from distinct age categories. Obviously, these practices should be properly accommodated and distributed over the soccer training routine, in order to maximize the speed-related adaptations and reduce the undesired concurrent effects.

The apparent contradiction of this study, however, lies in the substantial improvement in muscle power ability throughout the soccer age categories (Figure 1). Since our data revealed significant impairment in the prospective development of sprint performance, owing to the close relationships between power and speed (Cronin and Hansen, 2005), a similar response could also be expected in these neuromechanical capacities. Nevertheless, after analyzing the outcomes, we observed that the players presented meaningful increases of 10.4% and 11.5% (from U15 to U17 and from U17 to U20, respectively) in relative muscle power. A possible explanation for these dissimilarities between speed and power increases from U15 to U20 categories might be related to the inadequacy of training strategies employed during the players’ maturation, and a lack of a dedicated speed development program (Bate et al., 2014; Jeffreys, 2013). It would appear that simply focusing on strength and power attributes is insufficient to maximize speed development and that dedicated speed sessions should form an essential part of any soccer conditioning program (Bate et al., 2014). In this regard, Kotzamanidis et al. (2005) emphasized the necessity of combining both resistance and maximal sprint training in “the same training session”, to achieve better results in speed performance. This finding is also supported by other investigations (Maio Alves et al., 2010; Mujika et al., 2009a), which verified the efficacy of mixed training models (i.e., complex or contrast methods) in enhancing the speed ability of elite young soccer players. Therefore, besides the recommended adaptations in the total training content (i.e., increases in absolute frequency and relative volume of strength-power training), strength and conditioning coaches involved in

soccer are strongly suggested to adopt training schemes that combine strength, power, and sprint exercises in the overall training program.

Importantly, and similar to sprint performance, there was remarkable stabilization of muscle power capacity from U20 to senior, which was also noticed in a previous study involving these specific categories (Loturco et al., 2014). Although we observed a considerable increase in the total volume of neuromuscular training between these two age groups (Table 1), it is reasonable to assume that the disproportional intensification of typical soccer training (i.e., high amounts of technical-tactical sessions and matches) (Abade et al., 2014; Coutinho et al., 2015) during the senior phase strongly contributes to hampering the development of muscle power in elite athletes. As previously established (Coutts et al., 2007a; Kraemer et al., 2004), this increased loading with inadequate recovery time can induce actual signs of overreaching, thus leading to impaired strength and power performance. Thereby, to maximize the neuromechanical adaptations from resistance training in senior players, head coaches and technical staff should be aware of the importance of regularly implementing intensive (but not extensive) soccer-specific training methods (i.e., small-sided games; SSGs) in their professional routines. This practice may reduce the possible impairment in neuromuscular capacities, since it has been stated that SSGs do not negatively interfere with power-related performance (Loturco et al., 2015f; Owen et al., 2012). However, it is unlikely that these will be able to provide the dedicated speed training needed for optimal performance, and dedicated speed sessions are likely required if a player needs to optimize maximal speed performance, also ensuring that the player is optimally prepared for the speed runs that will be encountered in a game (Bate et al., 2014; Jeffreys and Goodwin, 2016).

Our findings are limited by the fact that only one professional soccer club was investigated, thus limiting the generalization of our findings. In addition, we did not consider the maturity groups within each age group to control for the effects of biological maturity status on the testing results (Deprez et al., 2015a). However, it is important to emphasize that dividing the players according to chronological age is an

ecologically valid approach since soccer federation rules are based on this maturation criterion to regulate the competitions. Similarly, the study did not analyze training undertaken by the players, as this also has the capacity to affect speed and power performance.

In summary, our results suggest that elite soccer players involved in development programs successfully improve their lower limb power-related capacities, as expressed by vertical jumping height and jump squat mean propulsive power, from the U15 to the senior category. However, the ability to accelerate over very-short distances (0-5 m) is highest in the U15 age-group, evidencing that from this early phase of their career, soccer players are not adequately prepared for high speed performance and potentially suffer from the effects of high volumes of technical-tactical training which appear to negatively interfere in the development of the neuromuscular ability to perform sprints. This fact culminates in “slower” senior players who must face the heavy requirements of progressively faster contemporary soccer matches.

## Conclusion

Contrary to the expected result, it appears that the evolution of speed performance in elite soccer throughout the prospective development of players is highly compromised by two distinct factors: 1) the ineffectiveness of the neuromuscular training strategies used by coaches, and 2) the imbalance between typical soccer endurance and strength-power-speed training. These data may have significant implications for creating more effective strategies to adequately increase neuromechanical capacities in this specific group of team sport athletes, frequently exposed to concurrent training effects, and all its adverse consequences (e.g., acceleration impairment over shorter distances). Based on these findings, strength and conditioning professionals involved in soccer are encouraged to constantly revise their daily methods and implement modern strength-power and speed training practices (i.e., mixed training approaches, optimum power loads, dedicated speed sessions, etc.) (Bate et al., 2014; Jeffreys and Goodwin, 2016; Loturco et al., 2015b, e, f; Loturco et al., 2016a, b), always in accordance with the scientific evidence.

Furthermore, soccer coaches should prioritize refining the sport-specific skills of their players and teams through the application of intensive (but not extensive) training loads, such as provided by the different forms of SSGs, and supplement these with speed specific development sessions. These arrangements can elicit the appropriate improvements in acceleration, speed, and power capacities of top-

level soccer athletes not only during the later stages of players' specialization, but also throughout their early phases of development. Further studies should be conducted to test the effectiveness of these suggested interventions during the distinct periods of soccer players' specialization.

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