Who runs the fastest? Anthropometric and physiological correlates of 20 m sprint performance in male soccer players

Nikolaidis, P T ; Ruano, M A G ; de Oliveira, N C ; Portes, L A ; Freiwald, J ; Leprêtre, P M ; Knechtle, B

Abstract: The aim of the present study was to examine the relationship of 20 m sprint performance with anthropometrical and physiological parameters in male soccer players. A hundred and 81 soccer players from the region of Athens (age 23.4 ± 5.0 yrs, body mass 73.4 ± 7.7 kg, height 180.0 ± 5.9 cm, body fat (BF) 14.4 ± 3.6%), classified into quartiles according to 20 m sprint time (group A, 2.84-3.03 s; group B, 3.04-3.09 s; group C, 3.10-3.18 s; group D, 3.19-3.61 s), participated. Soccer players in group A were younger and had better performance in vertical jumps and in the Wingate anaerobic test (WAnT, $p < 0.05$). Sprint time correlated to age ($r = 0.27$), body mass ($r = 0.23$), body height ($r = 0.20$), BF ($r = 0.23$), vertical jumps (-0.58 r -0.50) and the WAnT (-0.45 r -0.30, $p < 0.05$). In summary, the magnitude of correlations of sprint time with measures of lower limbs muscle strength and power (WAnT and jumps) was larger than with anthropometric measures (body mass and BF).

DOI: https://doi.org/10.1080/15438627.2016.1222281

Who run the fastest? Anthropometric and physiological correlates of 20 m sprint performance in male soccer players

Nikolaidis, P.T.[1], Ruano, M.A.G.[2], de Oliveira, N.C.[3], Portes, L.A.[3], Freiwald, J.[4], Leprêtre, P.M.[5], Knechtle, B.[6]

[1]Exercise Physiology Laboratory, Nikaia, Greece; [2]Faculty of Physical Activity and Sport Sciences, Universidad Politecnica de Madrid, Spain; [3]Research Group in Physical Exercise, Lifestyle and Health Promotion, Adventist University of Sao Paolo, Brazil; [4]Research Center for Performance Diagnostics and Training Advice, University of Wuppertal, Germany; [5]UFR-STAPS, Université de Picardie Jules Verne, Amiens, France; [6]Instutute of Primary Care, University of Zurich, Switzerland

Corresponding author

Pantelis Nikolaidis

Thermopylon 7, Nikaia 18450, Greece

T: +302104904023, M: +306977820298, F: +302104907557

pademil@hotmail.com

Who run the fastest? Anthropometric and physiological correlates of 20 m sprint performance in male soccer players

Abstract

The aim of the present study was to examine the relationship of 20m sprint performance with anthropometrical and physiological parameters in male soccer players. A hundred and eighty-one soccer players from the region of Athens (age 23.4±5.0 yrs, body mass 73.4±7.7 kg, height 180.0±5.9 cm, body fat, BF, 14.4±3.6%), classified into quartiles according to 20 m sprint time (group A, 2.84-3.03 s; group B, 3.04-3.09 s; group C, 3.10-3.18 s; group D, 3.19-3.61 s), participated. Soccer players in group A were younger and had better performance in vertical jumps and in the Wingate anaerobic test (WAnT, $p<0.05$). Sprint time correlated to age ($r=0.27$), body mass ($r=0.23$), body height ($r=0.20$), BF ($r=0.23$), vertical jumps ($-0.58 \le r \le -0.50$) and the WAnT ($-0.45 \le r \le -0.30$, $p<0.05$). In summary, the magnitude of correlations of sprint time with measures of lower limbs muscle strength and power (WAnT and jumps) was larger than with anthropometric measures (body mass and BF).

Keywords: acceleration, body composition, football, muscle strength, speed

Introduction

Soccer is an intermittent and high-intensity team sport where the players are required to perform sprints, jumps, kicks, and changes of direction during a match (Akenhead, Hayes, Thompson, & French, 2013; Carvalho et al., 2014). During soccer matches the running speed over short distances is a determinant factor of the players' performance, which is also influenced by other physiological and psychological factors (Dellal & Wong, 2013; Köklü, Alemdaroğlu, Özkan, Koz, & Ersöz, 2015; Pau, Ibba, Leban, & Scorcu, 2014). According to Kawamori, Hosaka, & Newton (2013) faster players have an advantage during the match and specifically during the critical moments due to they can get the ball in a counter-attack or recovering the ball in open spaces before than the opponent players. Specifically, the sprinting efforts during soccer matches are of short duration with ranges of 10 to 20 m and 2 to 3 seconds (Kawamori et al., 2013). Stolen, Chamari, Castagna & Wisløff (2005) found that 96% of the sprints performed during a match were shorter than 30 m, whereas half of them were shorter than 10 m.

In accordance with the abovementioned sport-specific demands, sprint ability has been routinely examined using 20 m linear sprints, usually consisting of two splits (i.e. 0-10 m and 10-20 m) (De Hoyo et al., 2015; Franco-Marque et al., 2015). Sprint ability is highly correlated to jumping performance (Faude, Roth, Giovine, Zahner, & Donath, 2013; Köklü et al., 2015), the running distance (Dellal & Wong, 2013), and quadriceps and upper body strength (Hrysomallis, Kosk, McCoy, Wrigley, & Club, 2013; Sander, Keiner, Schlumberger, Wirth, & Schmidtbleicher, 2013). In addition, sprint ability is influenced by the players' age (i.e., better performances in young players), the anthropometric characteristics (i.e., height and weight), the competitive level and the experience (i.e., highly skilled and experienced players presented better performances) (Dellal & Wong, 2013; Lago-Peñas et al., 2011).

However, the abovementioned studies did not reach a consensus with regards to the direction of these correlations. For instance, Lago-Peñas et al. (2011) have shown that heavier and taller soccer players performed faster in sprinting (30 m test) abilities in adolescence, whereas Nikolaidis, Dellal, Torres-Luque and Ingebrigtsen (2015) observed faster performance (repeated sprint ability) in the shorter and possibly lighter soccer players in adulthood. Given the importance of sprint performance for soccer, comprehending the correlates of sprint would be of great practical value for soccer coaches and fitness trainers. Therefore, the study of sprinting activity in soccer requires the need to account for independent factors that modify the players' performance such as age, anthropometric and physiological characteristics, and players' speed (Hrysomallis et al., 2013; Köklü et al., 2015).

Whereas the abovementioned studies have improved our understanding of correlates of sprint performance, to the best of our knowledge no study has ever profiled soccer players with high sprint performance or examined correlations of the 20m test with popular jump tests and the Wingate anaerobic test in a large sample. For instance, studies examining correlations among sprint ability, jumping and cycling performance used 23 (Chelly et al., 2010), 32 (Triki et al., 2012) or 36 soccer players (Nikolaidis, Dellal et al., 2015; Nikolaidis, Ingebrigtsen, & Jeffreys, 2015). A relatively small sample size might result in limitation to identify significant correlations, e.g. a study that observed correlations of sprint time with velocity and force during jumping but not with the height of vertical jump (Chamari et al., 2004). Therefore, the aims of the present study were: (a) to evaluate the relationship of sprint performance with anthropometric and physiological characteristics, and (b) to examine the profile of soccer players with high sprint performance with regards to their counterparts with lower ability.

Methods

Study design and participants

A group of 181 soccer players from the region of Athens (age 23.4±5.0 yrs, body mass 73.4±7.7 kg, height 180.0±5.9 cm, body fat 14.4±3.6%, see **Table 1**) voluntarily participated in the study. The participants were from various soccer clubs from the region of Athens, where they practiced 4-5 training sessions, each lasting ~90 min, and participated to a soccer match per week. These clubs competed to the third and fourth national leagues of Greece. The testing procedures were performed during the preparation period of seasons 2013-2014, 2014-2015 and 2015-2016. Eligibility criteria for this study were that the players would be free of injury or illness during the research analyses. They had been instructed to consume a meal of their choice, similar as that they used to before matches, two to three hours prior to each testing session. The local institutional review board approved this study and all participants provided their informed consent.

*** Please, insert Table 1 near here ***

Procedures and protocols

Each participant was tested during two sessions within a week and not in consecutive days. The first testing session took place in the laboratory, where they were examined for anthropometric characteristics (body height, body weight and skinfold thickness), vertical jumps and the WAnT. During the second testing session, they were tested in a 20 m sprint in the field. The warm up included a 10 min submaximal aerobic exercise and 10 min stretching exercises. Similar procedures of warm-up before sprinting and high-intensity tests have been used recently (Mann et al., 2015; Soares-Caldeira et al., 2013). This submaximal exercise was performed on a cycle ergometer in the first session and jogging in the second session.

Body height and weight were measured using a stadiometer (SECA, Leicester, UK) and an electronic scale (HD-351 Tanita, Illinois, USA), respectively. Body fat percentage (BF) was estimated by skinfold thickness (Harpenden, West Sussex, UK) in 10 sites (cheek, wattle, chest I, triceps, subscapular, abdominal, chest II, suprailiac, thigh and calf; $BF = -41.54 + 12.636 \times \log_e x$, where x the sum of 10 skinfolds) using Parizkova formula (Parizkova, 1978). Chronological age was calculated using a table of decimals of year (Ross & Marfell-Jones, 1991). All anthropometric measurements were performed according to the guidelines of ISAK (2001).

In the three single vertical jump tests (squat jump - SJ, countermovement jump - CMJ and Abalakov jump - AJ), participants were asked to jump as high as possible (Aragon-Vargas, 2000) over a photocell platform (Opto-jump, Microgate Engineering, Bolzano, Italy). The three tests were performed on a randomized order. Two trials were performed for each jump test and the best one was recorded for further analysis. The height of each jump was calculated from the flight time (Linthorne, 2001).

The WAnT was performed on a cycle ergometer (Ergomedics 874, Monark, Sweden) (Driss & Vandewalle, 2013). Participants were instructed to pedal as fast as possible for 30 s against a braking force that was determined by the product of body mass in kg by 0.075. The following three main indices of the WAnT were evaluated: (a) peak power (P_{peak}), (b) mean power (P_{mean}), and (c) fatigue index (FI). Both P_{peak} and P_{mean} were expressed in W and $W.kg^{-1}$. During this test, participants were encouraged verbally to exert maximal effort. Heart rate response to the WAnT was monitored by Team Pro (Polar Electro Oy, Kempele, Finland).

The 20 m sprint test was performed at an outdoor soccer synthetic pitch. The test was administered twice and the best trial was recorded for further analysis. Each trial, starting from a standing position with the front foot placed 0.5 m before the first pair of photocell, was timed using three pairs of electronic timing gates (Brower Timing System, Salt Lake City, USA) placed at 0, 10 and 20 m, and one meter above the ground.

Statistical analysis

Mean and standard deviations were calculated for all parameters. The Kolmogorov-Smirnov (K-S) test examined the distribution of data for normality. Since data were normally distributed ($p>0.05$ for K-S test), parametric statistics were used. Participants were grouped into quartiles, i.e. in four groups consisting of an equal number of participants in each one, according to the 20m sprint time (group A, 2.84-3.03 s; group B, 3.04-3.09 s; group C, 3.10-3.18 s; group D, 3.19-3.61 s). The use of four groups was performed in order to better match the individualised performance into groups of similar performance. Nowadays, there is a focus on adjusting the training, test and tasks according to the specific characteristics of the players (Gabbett, 2016). In particular, this fact would help the coaches and physical trainers tailoring and accurately planning for training avoiding injuries and overload (Gabbett, 2016). In a secondary application, the use of performance groups would facilitate talent identification from a physical point of view (sprinting). Four performance groups have been used previously in a study on youth categories in soccer (Coutinho et al., 2015). A one-way analysis of variance (ANOVA) compared A, B, C and D groups for anthropometric characteristics and short-term power. A one-way ANOVA was used to examine differences in anthropometric and physiological characteristics by playing position (goalkeepers, defenders, midfielders and forwards), too. Post-hoc analyses were performed using the Bonferroni test. The magnitude of the differences among groups was evaluated by eta square (η^2) as small ($0.01<\eta^2\leq0.06$), moderate ($0.06<\eta^2\leq0.14$) and large ($\eta^2>0.14$) (Cohen, 1988). A Pearson correlation analysis was performed between 20 m sprint and the other parameters. The magnitude of these correlations was evaluated as $r\leq0.1$, trivial; $0.1<r\leq0.3$, small; $0.3<r\leq0.5$, moderate; $0.5<r\leq0.7$, large; $0.7<r\leq0.9$, very large; and $r>0.9$, almost perfect (Hopkins, Marshall, Batterham, & Hanin, 2009). The significance level was set at alpha=0.05. A stepwise linear regression analysis was used to model the prediction of sprint ability from anthropometric and physiological parameters. The statistical software IBM SPSS 20.0 (SPSS, Chicago, USA) was used to perform all statistical analyses.

Results

The one-way analysis of variance showed significant differences among groups in age ($\eta^2=0.06$), SJ ($\eta^2=0.24$), CMJ ($\eta^2=0.25$), AJ ($\eta^2=0.30$), P_{peak} ($\eta^2=0.08$) and P_{mean} ($\eta^2=0.17$) in the WAnT ($p<0.05$) (**Table 2** and **3**). The magnitude of the differences among groups was small for age, moderate for P_{peak} and large for SJ, CMJ, AJ and P_{mean}. Body height ($p=0.054$, $\eta^2=0.04$) and BF ($p=0.063$, $\eta^2=0.04$) approached but did not quite achieve the statistically significant level (**Table 1**). The Bonferroni post-hoc test revealed that soccer players in the group A were younger and had better performance in SJ, CMJ, AJ, P_{peak} and P_{mean} ($p<0.05$), and were possibly shorter and with less BF than soccer players in the other groups (**Tables 1, 2 and 3**).

*** Please, insert Table 2 near here ***

*** Please, insert Table 3 near here ***

Sprint time was positively correlated (with small magnitude) with age, body mass, height, BF, and negatively (with moderate to large magnitude) with SJ, CMJ, AJ, P_{peak} and P_{mean} in $W.kg^{-1}$ (**Table 4**). The two split times had similar correlation with AJ, but differed with regards to P_{mean} in $W.kg^{-1}$ with larger magnitude for 10-20m split (**Figures 1** and **2**). The stepwise regression analysis indicated that predictors varied for each sprint parameter (**Table 5**).

*** Please, insert Table 4 near here ***

*** Please, insert Figure 1 near here ***

*** Please, insert Figure 2 near here ***

*** Please, insert Table 5 near here ***

With regards to anthropometric characteristics, the participants differed only for body mass ($p=0.009$, $\eta^2=0.08$), height ($p=0.031$, $\eta^2=0.06$) and fat-free mass ($p=0.017$, $\eta^2=0.07$) with moderate magnitude. Goalkeepers (78.1±6.2 kg, 181.5±6.5 cm) were heavier and taller than midfielders (71.5±8.1 kg, 176.4±5.4 cm), but not defenders (75.2±7.2 kg, 178.7±7.0 cm) or forwards (73.1±7.9 kg, 178.4±6.5 cm). Defenders (64.1±6.0 kg) had more fat-free mass than midfielders (61.3±5.2 kg), but not goalkeepers (65.3±4.8 kg) and forwards (62.8±5.3 kg). No difference by playing position was observed with regards to the sprint and physiological parameters.

Discussion

This study examined the relationship of 20 m sprint with three popular jump tests (SJ, CMJ and AJ) and the WAnT, and profiled according to their sprinting speed a relatively large (compared to previous studies) group of adult soccer players. There were two main findings in the present study. Firstly, 20 m sprint time correlated with all jump tests, the main indices of the WAnT (moderate to large magnitude) and anthropometric characteristics (small magnitude). Secondly, the fastest soccer players were younger (and possibly shorter and leaner) with superior performance in all the above-mentioned physiological tests than their counterparts with the slowest 20 m sprint time.

As was argued, the sprinting ability is affected by the age of the players, the skill level, the physiological and anthropometric characteristics, the strength and jumping performances (Padulo, Tabben, Ardigò et al., 2015; Padulo, Tabben, Attene et al., 2015). The present findings support the results obtained in the previous scientific research. According to Chamari et al. (2004) sprint, agility, and vertical jumping are closely related including dynamic actions that require high muscle power and strength. Additionally, these actions include the same energy systems reflecting the closely actions-related demands.

The correlation of 20 m sprint time with jump tests and the WAnT was in agreement with previous studies that used either a cross-sectional or longitudinal design. The relationship between sprint performance and muscle strength has been observed in cross-sectional studies (Comfort, Stewart, Bloom, & Clarkson, 2014; Nikolaidis, Dellal, et al., 2015). For example, 20 m time correlated largely with absolute and relative strength in back squat (Comfort et al., 2014). In another study, the best time of a repeated sprint ability test correlated low to moderately with BF, SJ, and P_{mean} (Nikolaidis, Dellal, et al., 2015). Moreover, evidence for the relationship between sprint performance and muscle strength was provided by studies using a longitudinal design and observing similar changes in both parameters over time (De Hoyo et al., 2015; Franco-Márquez et al., 2015), too. For instance, a 6-week resistance training program combined with plyometrics plus a soccer training program induced gains for both 20 m performance and CMJ (Franco-Márquez et al., 2015). Faude et al. (2013) identified that strength trained in combination with sprinting exercises resulted in greater adaptations in sprint speed as compared with strength training alone in high-level amateur soccer players. In another study on the effect of a plyometrics training program, including half-squat and leg-curl exercises, the experimental group improved both 20 m performance and CMJ (De Hoyo et al., 2015). Also, a study on adolescents showed that both 20m performance and CMJ increased over a 7-week plyometrics training program combined with soccer practice (Ramírez-Campillo et al., 2014). Finally, in a research on the effect of a 16-week plyometrics training program, gains in 20 m and standing broad jump were observed (Söhnlein, Müller, & Stöggl, 2014). On the contrary, both 20m and CMJ deteriorated after six weeks when playing two competitive matches per week (Rollo, Impellizzeri, Zago, & Iaia, 2014).

Compared to the physiological measures described above, the anthropometric characteristics (body mass, body height and BF) of participants correlated with 20 m sprint time with lower magnitude. According to the observed correlations in the present study, the higher (i.e. slower) was the sprint time, the taller, heavier and with more BF were the soccer player. These observations were in disagreement with the study of Lago-Peñas and et al. (2011), who found that heavier and taller young soccer players performed better in sprinting (30 m test) abilities. An explanation of this discrepancy might be the different age of participants (adults in the present study, adolescents in the study of Lago-Peñas et al., 2011). Moreover, this discrepancy highlighted the need to examine the correlates of sprint ability separately in adults from adolescents. On the contrary, our findings were in agreement with a previous study on Greek soccer players, in which those with faster repeated sprint ability were shorter (and possibly lighter with lower BF) than the slower soccer players (Nikolaidis, Dellal, et al., 2015).

On the other hand, the fastest soccer players were younger than the slowest players (and possibly shorter and leaner) with superior performance in all the above-mentioned physiological tests than their counterparts with slower 20m time. In rugby league players, a comparison between fast and slow athletes according to 5m sprint time showed that the fast one were faster in 10m, 30m, and jumped higher in SJ and CMJ (Cronin & Hansen, 2005). In another study, a negative correlation between sprint time and isokinetic quadriceps muscle strength was observed (Hrysomallis et al., 2013). Finally, the findings of the comparison among groups differing for 20m sprint time were in agreement with the results of the correlation analysis. These results show that the anthropometric and fitness assessment of elite youth soccer players can play a key role in determining their chances to achieve a higher competitive level (le Gall, Carling, Williams, & Reilly, 2010). In fact, the qualitative adaptations that accompany the player's maturation are important for correlations between players' speed and age (Mendez-Villanueva et al., 2011). Faude et al. (2013) argued that the maturational process was a significant moderator variable that modifies the effect of the strength training during the critical period of maturation between 18 to 22 years of age (i.e., a period of years close to the sample used in the present study). Thus, the age, biological maturity or years of training affect the players' physical and physiological profiles such as speed or sprinting (Lago-Peñas et al., 2011).

A limitation of the present study was that the findings concerned soccer players of a certain sprint level and variability. Thus, they should not be generalized to groups of soccer players with different level or range of scores. With regards to the role of playing position, there was no effect on physiological characteristics, which might be attributed to need for larger sample size to study this effect. Although the correlations of sprint performance with anthropometric and physiological characteristics did not prove a causal relationship, the knowledge of correlates of sprint performance might help coaches and fitness trainers optimizing their training focusing on sprint. In addition, the practitioners working with soccer players can benefit from the findings of the present study by using them as reference data in the evaluation of physical fitness. This is of great practical value considering that the data concerned widely used testing protocols. Considering the increased scientific interest for the sprint ability in soccer, researchers in the field of soccer performance might use our results as reference in their future studies.

Conclusions

Considering the findings from a practical point of view, a major prerequisite for performance in elite soccer level is to have a well-developed physical fitness. Thus, coaches, fitness trainers and sport scientists working with soccer players should be aware of the anthropometric and physiological factors correlated to 20m sprint time. The magnitude of correlations of sprint time with measures of lower limbs muscle strength and power (WAnT and jumps) was larger than with anthropometric measures (body mass and BF). Therefore, the focus of sprint training should be primarily on muscle strength and power, and secondarily on body composition management. Considering the older age of the slowest group and the correlation between age and sprint time, coaches and trainers should develop exercise programs targeting sprint performance especially in the older soccer players. In addition, they should concentrate on exercise and nutrition programs aiming to optimize body mass and BF since lower values of both were associated with better sprint performance.

References

Akenhead, R., Hayes, P. R., Thompson, K. G., & French, D. (2013). Diminutions of acceleration and deceleration output during professional football match play. *Journal of Science and Medicine in Sport, 16*, 556–561.

Aragon-Vargas, L. F. (2000). Evaluation of four vertical jump tests: Methodology, reliability, validity, and accuracy. *Measurement in Physical Education and Exercise Science, 4*, 215–228.

Carvalho, H. M., Bidaurrazaga-Letona, I., Lekue, J. A., Amado, M., Figueiredo, A. J., & Gil, S. M. (2014). Physical growth and changes in intermittent endurance run performance in young male Basque soccer players. *Research in Sports Medicine, 22*, 408-424.

Chamari, K., Hachana, Y., Ahmed, Y. B., Galy, O., Sghaïer, F., Chatard, J. C., et al. (2004). Field and laboratory testing in young elite soccer players. *British Journal of Sports Medicine, 38*, 191–196.

Chelly, M. S., Ghenem, M. A., Abid, K., Hermassi, S., Tabka, Z., & Shephard, R. J. (2010). Effects of in-season short-term plyometric training program on leg power, jump-and sprint performance of soccer players. *Journal of Strength and Conditioning Research, 24*, 2670–2676.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Comfort, P., Stewart, A., Bloom, L., & Clarkson, B. (2014). Relationships between strength, sprint, and jump performance in well-trained youth soccer players. *Journal of Strength and Conditioning Research, 28*, 173–177.

Coutinho, D., Gonçalves, B., Figueira, B., Abade, E., Marcelino, R., & Sampaio, J. (2015). Typical weekly workload of under 15, under 17, and under 19 elite Portuguese football players. *Journal of Sports Sciences*, *33*, 1229-1237.

Cronin, J. B., & Hansen, K. T. (2005). Strength and power predictors of sports speed. *Journal of Strength and Conditioning Research, 19*, 349–357.

De Hoyo, M., Pozzo, M., Sañudo, B., Carrasco, L., Gonzalo-Skok, O., Domínguez-Cobo, S., et al. (2015). Effects of a 10-week in-season eccentric-overload training program on muscle-injury prevention and performance in junior elite soccer players. *International Journal of Sports Physiology and Performance, 10*, 46–52.

Dellal, A., & Wong, D. P. (2013). Repeated sprint and change-of-direction abilities in soccer players: Effects of age group. *Journal of Strength and Conditioning Research, 27*, 2504–2508.

Driss, T., & Vandewalle, H. (2013). The measurement of maximal (anaerobic) power output on a cycle ergometer: a critical review. *Biomed Res Int, 2013*, 589361.

Faude, O., Roth, R., Giovine, D. D., Zahner, L., & Donath, L. (2013). Combined strength and power training in high-level amateur football during the competitive season: A randomised-controlled trial. *Journal of Sports Sciences, 31*, 1460–1467.

Franco-Márquez, F., Rodríguez-Rosell, D., González-Suárez, J. M., Pareja-Blanco, F., Mora-Custodio, R., Yañez-García, J. M., et al. (2015). Effects of combined resistance training and plyometrics on physical performance in young soccer players. *International Journal of Sports Medicine, 36*, 906–914.

Gabbett, T. J. (2016). The training—injury prevention paradox: Should athletes be training smarter and harder? *British Journal of Sports Medicine*, *50*, 273-280.

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise, 41*, 3–13.

Hrysomallis, C., Kosk, R., McCoy, M., Wrigley, T., & Club, R. F. (2013). Correlations between field and laboratory tests of strength, power and muscular endurance for elite Australian rules footballers. In A. Murphy & T. Reilly (Eds.), *Science and Football IV*. London: Routledge.

ISAK (2001). *International standards for anthropometric assessment*. Underdale, Australia: The University of South Australia.

Kawamori, N., Nosaka, K., & Newton, R. U. (2013). Relationships between ground reaction impulse and sprint acceleration performance in team sport athletes. *Journal of Strength and Conditioning Research, 27*, 568–573.

Köklü, Y., Alemdaroğlu, U., Özkan, A., Koz, M., & Ersöz, G. (2015). The relationship between sprint ability, agility and vertical jump performance in young soccer players. *Science and Sports, 30*, e1–e5.

Lago-Peñas, C., Casais, L., Dellal, A., Rey, E., & Domínguez, E. (2011). Anthropometric and physiological characteristics of young soccer players according to their playing positions: Relevance for competition success. *Journal of Strength and Conditioning Research, 25*, 3358–3367.

le Gall, F., Carling, C., Williams, M., & Reilly, T. (2010). Anthropometric and fitness characteristics of international, professional and amateur male graduate soccer players from an elite youth academy. *Journal of Science and Medicine in Sport, 13*, 90–95.

Linthorne, N. P. (2001). Analysis of standing vertical jumps using a force platform. *American Journal of Physics, 69*, 1198–1204.

Mann, J. B., Ivey, P. J., Brechue, W. F., & Mayhew, J. L. (2015). Validity and Reliability of Hand and Electronic Timing for 40-yd Sprint in College Football Players. *Journal of Strength and Conditioning Research*, *29*, 1509-1514.

Mendez-Villanueva, A., Buchheit, M., Kuitunen, S., Douglas, A., Peltola, E., & Bourdon, P. (2011). Age-related differences in acceleration, maximum running speed, and repeated-sprint performance in young soccer players. *Journal of Sports Sciences, 29*, 477–484.

Nikolaidis, P. T., Dellal, A., Torres-Luque, G., & Ingebrigtsen, J. (2015). Determinants of acceleration and maximum speed phase of repeated sprint ability in soccer players: A cross-sectional study. *Science and Sports, 30*, e7–e16.

Nikolaidis, P. T., Ingebrigtsen, J., & Jeffreys, I. (2015). The effects of anthropometry and leg muscle power on drive and transition phase of acceleration: a longitudinal study on young soccer players. *J Sports Med Phys Fitness, epub ahead of print.*

Padulo, J., Tabben, M., Ardigò, L. P., Ionel, M., Popa, C., Gevat, C., Zagatto, A. M., & Dello Iacono, A. (2015). Repeated sprint ability related to recovery time in young soccer players. *Research in Sports Medicine, 23*, 412–423.

Padulo, J., Tabben, M., Attene, G., Ardigò, L. P., Dhahbi, W., & Chamari, K. (2015). The impact of jumping during recovery on repeated sprint ability in young soccer players. *Research in Sports Medicine, 23*, 240-252.

Parizkova, J. (1978). Lean body mass and depot fat during autogenesis in humans. In J. Parizkova & V. Rogozkin (Eds.), *Nutrition, Physical Fitness and Health: International Series on Sport Sciences*. Baltimore: University Park Press.

Pau, M., Ibba, G., Leban, B., & Scorcu, M. (2014). Characterization of static balance abilities in elite soccer players by playing position and age. *Research in Sports Medicine, 22*, 355-367.

Ramírez-Campillo, R., Meylan, C., Álvarez, C., Henríquez-Olguín, C., Martínez, C., Cañas-Jamett, R., et al. (2014). Effects of in-season low-volume high-intensity plyometric training on explosive actions and endurance of young soccer players. *Journal of Strength and Conditioning Research, 28*, 1335–1342.

Rollo, I., Impellizzeri, F. M., Zago, M., & Iaia, F. M. (2014). Effects of 1 versus 2 games a week on physical and subjective scores of subelite soccer players. *International Journal of Sports Physiology and Performance, 9*, 425–431.

Ross, W. D., & Marfell-Jones, M. J. (1991). Kinanthropometry. In J. D. MacDougall, H. A. Wenger & H. J. Green (Eds.), *Physiological testing of the high-performance athlete*. Champaign, IL: Human Kinetics.

Sander, A., Keiner, M., Schlumberger, A., Wirth, K., & Schmidtbleicher, D. (2013). Effects of functional exercises in the warm-up on sprint performances. *Journal of Strength and Conditioning Research, 27*, 995–1001.

Söhnlein, Q., Müller, E., & Stöggl, T. L. (2014). The effect of 16-week plyometric training on explosive actions in early to mid-puberty elite soccer players. *Journal of Strength and Conditioning Research, 28*, 2105–2114.

Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of soccer: An update. *Sports Medicine, 35*, 501–536.

Triki, M., Rebai, H., Abroug, T., Masmoudi, K., Fellmann, N., Zouari, N., et al. (2012). Comparative study of body composition and anaerobic performance between football and judo groups. *Science and Sports, 27*, 293–299.

Table 1. Anthropometric characteristics of soccer players according to sprinting performance.

	Total (n=181)	Group A (n=45)	Group B (n=48)	Group C (n=44)	Group D (n=44)
Age (yrs)	23.4±5.0	21.8±3.8^{D}	22.9±4.5	24.0±5.4	25.0±6.0^{A}
BM (kg)	73.4±7.7	71.4±6.5	73.1±7.7	73.9±9.0	75.4±7.3
Body height (cm)	178.2±6.5	176.8±6.9	177.0±6.4	179.0±6.5	180.0±5.9
BMI (kg.m^{-2})	23.1±1.8	22.8±1.4	23.3±1.6	23.0±1.9	23.3±2.4
BF (%)	14.4±3.6	13.4±2.8	14.1±3.7	15.1±3.7	15.1±4.0

Values were presented as means ± standard deviations. The soccer players were grouped by performance in the 20 m sprint. BM = body mass, BMI = body mass index; BF = body fat percentage. Letters A, B, C and D shown as superscripts denoted significant difference from group A, B, C and D, respectively, at $p<0.05$.

Table 2. Lower limb power of soccer players according to sprinting performance.

	Total (n=181)	Group A (n=45)	Group B (n=48)	Group C (n=44)	Group D (n=44)
SJ (cm)	34.9±4.6	38.1±4.8^{C,D}	35.9±3.8^{C,D}	33.4±4.1^{A,B}	32.1±3.6^{A,B}
CMJ (cm)	36.3±4.9	39.9±5.2^{B,C,D}	36.9±4.2^{A,D}	34.6±3.7^{A}	33.5±4.0^{A,B}
AJ (cm)	43.2±5.0	47.0±4.8^{B,C,D}	44.6±3.9^{A,C,D}	41.2±3.7^{A,B}	40.0±4.4^{A,B}

Values were presented as means ± standard deviations. The soccer players were grouped by performance in the 20 m sprint. SJ = squat jump, CMJ = countermovement jump, AJ = Abalakov jump. Letters A, B, C and D shown as superscripts denoted significant difference from the corresponding group at $p<0.05$.

Table 3. Main indices of the Wingate anaerobic test of soccer players according to sprinting performance.

	Total (n=181)	Group A (n=45)	Group B (n=48)	Group C (n=44)	Group D (n=44)
P_{peak} (W)	846±118	847±121	857±116	839±132	841±104
P_{peak} ($W.kg^{-1}$)	11.52±0.97	11.83±1.07^{D}	11.70±0.75^{D}	11.34±0.95	11.17±1.00^{A,B}
P_{mean} (W)	643±80	652±75	651±78	633±90	633±75
P_{mean} ($W.kg^{-1}$)	8.75±0.68	9.13±0.63^{C,D}	8.89±0.59^{D}	8.57±0.60^{A}	8.40±0.68^{A,B}
FI (%)	44.5±7.8	43.6±7.8	45.1±7.4	44.6±8.7	44.7±7.4
HR_{WAnT} (bpm)	179±11	180±12	180±9	177±13	178±11

Values were presented as means ± standard deviations. The soccer players were grouped by performance in the 20 m sprint.

P_{peak} = peak power; P_{mean} = mean power; FI = fatigue index, HR_{WAnT} = peak heart rate response to the Wingate anaerobic test. Letters A, B, C and D shown as superscripts denoted significant difference from the corresponding group at $p<0.05$.

Table 4. Correlations of sprint time with anthropometric and physiological characteristics.

	20 m sprint time (s)	0-10 m split time (s)	10-20 m split time (m)
Age (yrs)	0.27†	0.22*	0.26†
BM (kg)	0.23†	0.23†	0.16*
Body height (cm)	0.20†	0.23†	0.11
BMI (kg.m^{-2})	0.13	0.11	0.12
BF (%)	0.23†	0.14	0.29‡
FFM (kg)	0.16*	0.21†	0.04
SJ (cm)	–0.50‡	–0.41‡	–0.48‡
CMJ (cm)	–0.52‡	–0.43‡	–0.48‡
AJ (cm)	–0.58‡	–0.49‡	–0.53‡
P_{peak} (W)	–0.02	0.04	–0.09
P_{peak} (W.kg^{-1})	–0.30‡	–0.21†	–0.33‡

P_{mean} (W)	–0.09	–0.01	–0.18
P_{mean} ($W.kg^{-1}$)	–0.45‡	–0.31‡	–0.51‡
FI (%)	0.05	0.03	0.06

BM = body mass, BMI = body mass index; BF = body fat percentage, FFM = fat-free mass, SJ = squat jump, CMJ = countermovement jump, AJ = Abalakov jump, P_{peak} = peak power; P_{mean} = mean power; FI = fatigue index. *p<0.05, †p<0.01, ‡p<0.001

Table 5. Prediction models of 20 m sprint time, 0-10 m and 10-20 split times from anthropometric and physiological measures.

	Predictors	*R*	R^2	*SEE*	Prediction equation
20 m sprint time (s)	AJ, Age, P_{mean}	0.64	0.41	0.10	$y = 3.819 – 0.011 \times AJ + 0.004 \times Age – 0.034 \times P_{mean}$
0-10 m split time (s)	AJ, FFM	0.56	0.31	0.07	$y = 1.969 – 0.009 \times AJ + 0.004 \times FFM$
10-20 m split time (s)	P_{mean}, AJ	0.61	0.37	0.05	$y = 1.740 – 0.031 \times P_{mean} – 0.004 \times AJ$

AJ = Abalakov jump, P_{mean} = mean power in the Wingate anaerobic test, FFM = fat-free mass, *R*=multiple correlation coefficient, R^2=multiple coefficient of determination and *SEE*=standard error of estimate. Predictors are presented in order according to stepwise linear regression analysis.

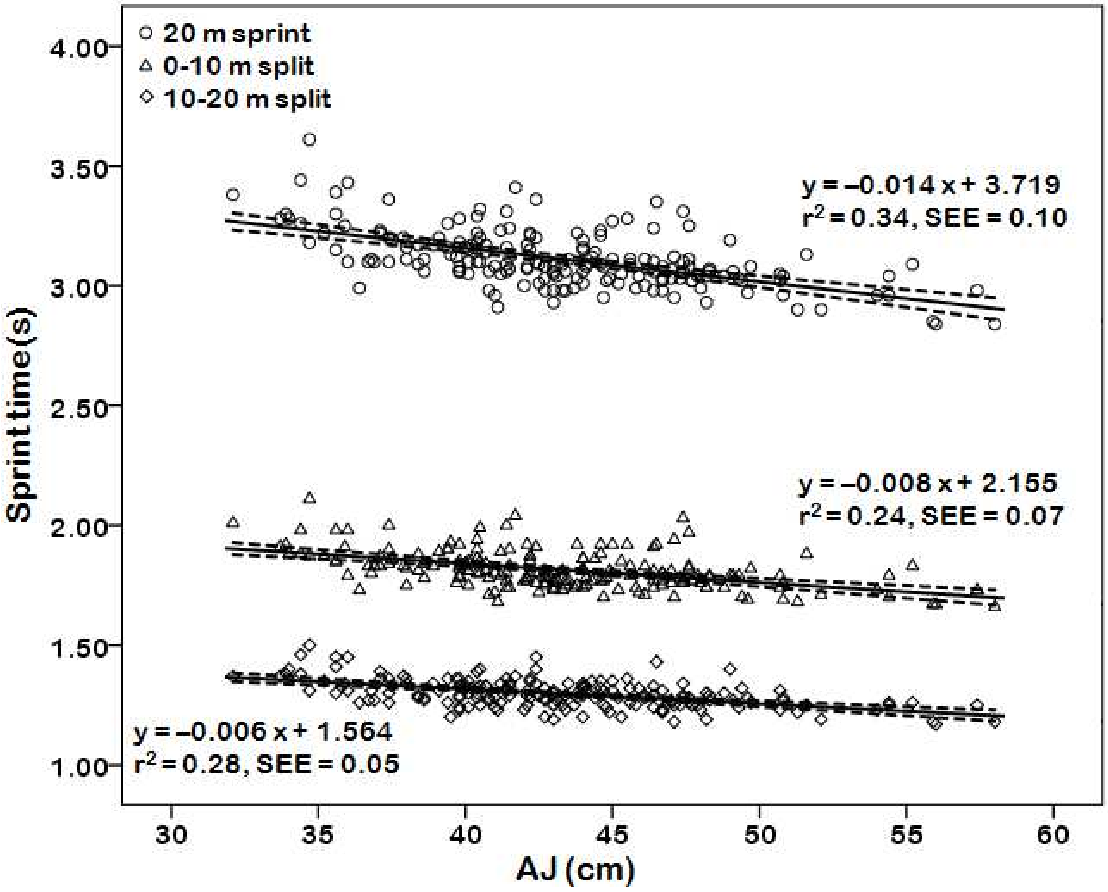

Figure 1. Relationship of performance in 20 m sprint, 0-10 m and 10-20 m split with Abalakov jump (AJ). r^2 = coefficient of determination, SEE = standard error of the estimate.

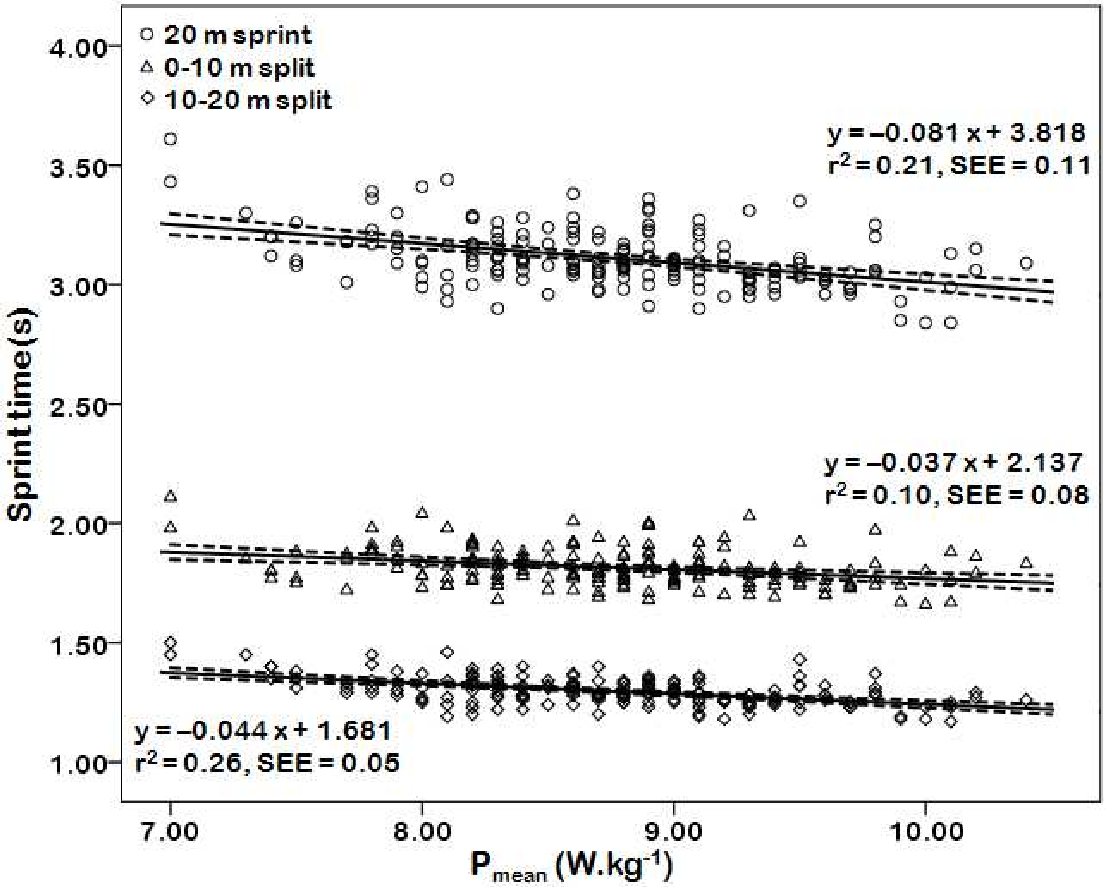

Figure 2. Relationship of performance in 20 m sprint, 0-10 m and 10-20 m split with relative mean power of the Wingate anaerobic test (P_{mean}). r^2 = coefficient of determination, SEE = standard error of the estimate.