How to cite: Santos DAN, Eiras FGM, Gonet DT, Robalinho MJA, Vasconcelos FVA. Relationship between functional movement screen and physical performance in elite young soccer players. Rev Bras Fisiol Exerc 2021;20(2):200-211. doi: 10.33233/rbfex.v20i2.4313

RBFEx
ISSN Online: 2675-1372

Revista Brasileira de Fisiologia do Exercício

Original article

Relationship between functional movement screen and physical performance in elite young soccer players

Relação entre a avaliação funcional do movimento e performance física em jovens atletas de elite do futebol

Diêgo Augusto Nascimento Santos[1], Fábio Garcia Madalen Eiras[1], Deborah Touguinhó Gonet[1], Maria Juliana de Almeida Robalinho[1], Fabrício Vieira do Amaral Vasconcelos[1]

1. Universidade do Estado do Rio de Janeiro, Rio de Janeiro, RJ, Brazil

ABSTRACT
Background: Soccer performance can be analyzed by different physical parameters such as linear speed and power. In addition, movement quality evaluations are used to assess individual functional capacity and a widely used tool is the functional movement screen (FMS). **Objectives:** The present study had three aims: 1) analyse the association of FMS final score and individual FMS scores with peak and relative muscle power and 10-m and 30-m sprints of young soccer players; 2) analyse the association between muscle power and speed from different categories controlled by FMS score; 3) compare peak and relative muscle power and 10-m and 30-m sprints between athletes with results of FMS >14 and < 14 scores in different categories. **Methods:** Fifty-six Brazilian players from U15, U17, and U20 participated in the research. Subjects performed anthropometric measurements, FMS, muscle power, and 10-m, and 30-m sprint. **Results:** The results did not show association between FMS score and muscle power and speed ($p > 0.05$). However, stability-push-up showed small association with peak and relative muscle power ($r = 0.28$, $p < 0.05$; $r = 0.29$, $p < 0.05$, respectively). The in-line-lunge test showed inverse and small correlation with 10-m sprint ($r = -0.28$; $p < 0.05$). Relationship between peak and relative muscle power with 10-m and 30-m sprints showed moderate and small association in all categories, respectively ($r = -0.76$-0.32, $p = 0.01$). In addition, it was not found difference among players above and below 14 score. **Conclusion:** Based on these findings, the 14 score shows to be a weak cut-off value and it can be assumed that there are no association between FMS and power and speed in youth soccer.

Keywords: athletic performance; physical functional performance; athletes; physical fitness; soccer.

RESUMO
Introdução: A *performance* no futebol pode ser analisada por diferentes parâmetros físicos como velocidade linear e potência. Além disso, a avaliação da qualidade de movimento é utilizada para verificar a capacidade funcional individual e uma ferramenta bastante utilizada é a avaliação funcional do movimento (FMS - Functional Movement Screen). **Objectives:** O presente estudo teve três objetivos: 1) analisar a relação da pontuação final e individual do FMS com a potência muscular e velocidade em jovens jogadores de futebol; 2) analisar a relação da potência muscular com a velocidade, controlada pela pontuação do FMS, de diferentes categorias; 3) comparar potência muscular e velocidade entre os atletas de diferentes categorias com pontuação do FMS <14 e >14. **Métodos:** Participaram 56 jogadores brasileiros (Sub-15, Sub-17 e Sub-20). Os atletas realizaram medidas antropométricas, FMS, teste de potência muscular e velocidade. **Resultados:** Os resultados mostraram que não houve correlação entre a pontuação do FMS e potência muscular e velocidade ($p > 0,05$). Entretanto, a flexão de braço mostrou uma correlação pequena com potência muscular máxima e relativa ($r = 0,28$, $p < 0,05$; $r = 0,29$, $p < 0,05$, respectivamente). O agachamento unilateral mostrou uma correlação pequena e inversa com sprint de 10 m ($r= -0,28$; $p < 0,05$). A relação entre potência muscular com sprints de 10 e 30 m mostrou uma correlação moderada e pequena, respectivamente, em todas as categorias ($r= -0,76$-$0,32$, $p = 0,01$). Além disso, não foi encontrada diferença entre os jogadores que apresentaram valores abaixo e acima de 14. **Conclusão:** Baseado nos achados, a pontuação 14 no FMS parece ser um fraco valor de corte, assim como parece não haver relação do FMS com potência e velocidade em jovens jogadores de futebol.

Palavras-chave: desempenho atlético; desempenho físico funcional; atletas; aptidão física; futebol.

Recebido em: 29 de julho 2020; Aceito em: 25 de março 2021.

Correspondência: Fabrício Vieira do Amaral Vasconcelos, Rua São Francisco Xavier, 524 sala 8133 bloco F, 20550-900 Rio de Janeiro RJ. fabricio.vasconcellos@uerj.br

Introduction

Soccer is considered an intermittent energy-intensive sport, predominantly involving the aerobic system [1-4]. However, the moments that determine the soccer game are characterized by strength, power, change of direction and speed actions, also demonstrating great importance of the anaerobic system in this sport [5]. Thus, evaluating and developing these core skills is necessary to promote the high level of performance for players [6]. In addition, in recent years, the interest of researchers and coaches in assessing and improving the athlete's functional capacity has grown and it is considered extremely important to improve the athletes' performance [7,8].

Soccer performance assessment is based on different parameters and it could include linear speed tests, change of direction, lower limb muscle power, anaerobic capacity and strength [9,10]. Studies about performance have shown associations between lower limb muscle power assessment in linear transducer and speed in sprint test in different modalities [11,12]. In recent years, new technologies have been used to measure muscle power in elite athletes, and one example is device with pneumatics resistance. This technology allows great resemblance to sports gestures since resistance always remains constant during movement [13,14]. This pneumatic resistance characteristic can explain why have been increasing the number of studies with this procedure to evaluate power in soccer [15]. Nevertheless, the number of researches that associate squat and pneumatic resistance and speed in soccer players is limited.

Moreover, observe the athlete's ability to perform basic movement patterns have also been used as part of performance evaluation, and for some authors, it is related with high performance in sprints and muscle power movements [16,17]. Thus, some studies have suggested the use of the functional movement screen (FMS) as a simple tool that evaluates common movement patterns in sports [16,18]. The FMS is an assessment created by Cook *et al.* [19,20] to measure the individual functional capacity of athletes. The tool consists of performing seven fundamental human movement patterns that require mobility, stability and motor control and its score ranges from 0 to 21 points. The literature has suggested that a final score <14 is a cut-off value to correlate with increased risk of injury [21]. However, some recent studies have shown that there is not always a relation between FMS score and risk of injury [22,23]. Although many studies have shown moderate-reliability values [22], FMS is a low-cost method and therefore accessible to many teams. Several clubs in the major leagues all around the world continue to use this tool as part of the athletes' assessment, which justifies further research not only to associate the FMS with the risk of injury but also with sports performance.

Few studies have searched associations between FMS final score and performance variables in soccer athletes [16,18,24]. Lee *et al.* [24] verified that FMS score could affect speed and agility of elite male collegiate soccer players and Lloyd *et al.* [18] found moderate and high correlation between FMS total score and strength, power and agility in young soccer athletes. However, Silva *et al.* [16] did not demonstrate a relation between FMS total score and performance variables, although the authors presented small associations with FMS individual scores in U-16 and U-19. Besides soccer, studies with other sports and non-athletes also showed inconclusive results regarding associations between FMS score and squat jump, agility, strength and anaerobic capacity. One of the reasons for this inconclusion can be the different variables and distinct performance tests in studies [16,18,24]. Moreover, none studies until the moment have used pneumatic equipment to assess muscle power and to associate it with movement pattern and FMS individual scores.

Therefore, further studies are needed to observe the correlations of FMS with performance parameters in young soccer players. In this context, the present study has three aims: 1) analyze the association of FMS final score and individual FMS scores with peak and relative muscle power and 10-m and 30-m sprints of young soccer players; 2) analyze the association between muscle power and speed from different categories controlled by FMS score; 3) compare peak and relative muscle power and 10-m and 30-sprints between athletes with results of FMS > 14 and < 14 in different categories. The assumption is that there is a small association between the result of the FMS and performance variables and FMS score is expected to improve the power and speed association. In addition, it is not supposed to have difference between athletes with results of FMS >14 and <14.

Methods

The present cross-sectional study aimed to examine the associations between movement pattern with lower limb muscle power and 10- and 30-meters sprints of young soccer athletes of different categories. The subjects performed all tests on the same day, in the following order: 1) anthropometric measurements; 2) functional movement screen (FMS); 3) Muscle power; 4) 10-m and 30-m sprints. The subjects were familiar with the tests and they were instructed as to the procedure. After completing the FMS, the athletes performed a 5-min general warm-up on a cycle ergometer and subsequently they were conducted to the lower limb muscle power and speed tests, respectively. It was observed a 15-minute rest interval between each test, and all evaluations took place between 9:00 a.m. and 1:00 p.m.

The sample consisted of 56 young Brazilian soccer players from an elite club, divided into U15, U17, and U20 (N = 9, 29 and 18, respectively). Inclusion criteria were, a) to be in the club for at least 6 months; b) not having suffered injuries in the last 3 months and as exclusion criteria was considered not to complete the test battery. The athletes were in the club's pre-season and individual interviews were conducted explaining the importance of the assessment, subsequently, all players signed the informed consent form in accordance with the Declaration of Helsinki. All players were familiar with the physical testing procedures and requirements. The research was approved on 22 July 2016 by the ethics committee of the Rio de Janeiro State University under the responsibility of Lucas Ometto with the protocol number 1645377.

Anthropometrics

Body mass and height were measured according to standard procedures (Lohman, 1986). Body mass was assessed with a digital scale (Filizola TM, SaoPaulo, SP, Brazil) and height with a fixed stadiometer (Sanny TM, São Paulo, SP, Brazil).

Functional movement screen

FMS is a subjective analysis tool based on the evaluation of fundamental movement patterns, according to seven standards: deep squat, hurdle step, in line lunge, shoulder mobility, active straight leg raises, trunk stability push-up, and rotary stability. Three repetitions were performed and the best one was used for analysis, the evaluated patterns followed in a scale from 0 to 3, represented according to the criteria. Score 3: achievement of perfect motion, without compensations, meeting the movement expectations of the pattern associated with each test. Score 2: complete the movement but using standard motion compensations. Score 1: the subject is unable to perform the movement pattern or unable to assume the starting position to perform the movement. Score 0: the individual feels pain when performing the movement. The subjects returned the starting position between each attempt and at the end, the maximum score could reach 21 points. Except for deep squat and trunk stability push-up, all movements were evaluated bilaterally. The FMS was applied by a certified evaluator with two years of experience. After obtaining the final score, the athletes were divided into two groups, group with score <14 and group with score >14 [19,20].

10-m and 30-m Sprints

The athletes performed two submaximal 30-m sprints attempts. After an interval of 5 minutes, they started the test in the stationary position and completed two maximum 30-m sprints attempts with a 60-second interval between them. Three pairs of photocells (Brower Timing Systems, USA) were used at positions 0-m, 10-m and 30-m. Players were instructed to run as fast as possible until they exceeded the final photocell pair, the best attempt was considered for analysis.

Squat power pneumatic test

It was used the Keiser Air 300Squat Machine (Keiser, Fresno, USA) to determine peak power, which is a pneumatic strength and power measurement machine. The consisted warm-up performed included 5 minutes of cycling at 50W on a cycle ergometer, followed by 10 squats at 40% of the athletes' body mass. Participants were instructed to position themselves on the equipment with their feet hip-width apart and to place their hands on the equipment rod, afterwards the resistance was placed on both shoulders. Players started the test from the standing position and they were instructed to perform a finding up to the 90º squat position (measured with a digital goniometer – Global Medical Devices; Maharashtra, India), maintaining for 3 seconds, and afterward a complete extension at the maximum concentric speed of the knees, hip, and ankle, triple extension movement. Each individual started with a load equivalent to 100% of body weight. An ultrasonic system mounted on the pneumatic cylinder is responsible for printing charge to motion and monitoring relative motion over time, allowing the calculation of distance and speed, therefore work and power. These values are displayed on a configurable digital display [14]. Subsequently, the relative power was calculated using the power peak divided by the bodyweight of each athlete.

Statistical analysis

Data were presented as mean ± standard deviation. Sample normality was analyzed using the Kolmogorov Smirnov test. Student's t-test for independent samples was used for comparisons within the groups (FMS > 14 vs FMS < 14). Pearson's product-moment correlation coefficient was used to determine associations between FMS scores, peak power, relative power, and 10m and 30m sprints and partial correlation was used to determine associations between FMS score and power in sprint. It was used Hedges' g to measure effect size, considering insignificant (< 0.19), small (0.20-0.49), medium (0.50-0.79), large (0.80-1.29) and very large (> 1.30) [25]. The significance level adopted was $p < 0.05$ and the analyses were performed using IBM SPSS for Windows version 25.0.

Results

Table I shows descriptive statistics regarding physical variables. Table II shows the correlation values between the individual scores and the total FMS and the performance variables. It was found a small and inverse correlation between in line lunge and 10-m Sprint ($r = -0.28$; $p = 0.03$), also small correlations were observed between trunk stability push-up tests and power: peak ($r = 0.28$; $p = 0.03$) and relative ($r = 0.29$; $p = 0.03$).

Table I – Descriptive statistics (mean ± SD) of physical variables

	U15 (N = 9)	U17 (N = 29)	U20 (N = 18)
Height (cm)	173.12 ± 6.03	178.50 ± 6.23	177.79 ± 6.11
Weight (kg)	64.46 ± 4.13	72.48 ± 8.42	71.65 ± 5.98
FMS Score	13.88 ± 1.83	14.82 ± 1.41	15.05 ± 2.04
Peak Power (W)	1727.77 ± 221	2056.51 ± 334	1820.16 ± 265
Relative Power (W/kg)	27.44 ± 1.69	28.57 ± 3.02	25.56 ± 2.77
10-M Sprint (s)	1.78 ± 0.05	1.78 ± 0.08	1.68 ± 0.05
30-M Sprint (s)	4.23 ± 0.15	4.17 ± 0.12	4.05 ± 0.12

Rev Bras Fisiol Exerc 2021;20(2):200-211

Table II – Correlation between individual function movement screen scores and performance variables for all categories

	Peak Power	Relative Power	10-m Sprint	30-m Sprint
Deep squat	-0.10	-0.14	-0.02	-0.06
Hurdle step	-0.16	-0.15	-0.01	0.01
In line lunge	-0.29	-0.11	-0.28*	0.13
Shoulder mobility	-0.17	0.12	0.17	0.20
Active straight leg raise	0.16	-0.03	-0.02	-0.14
Trunk stability push-up	0.28*	0.29*	-0.25	-0.14
Rotary stability	0.09	0.15	0.25	0.13
Total score	-0.10	0.10	-0.07	-0.04

*Correlation was significant at level 0.05; **Correlation was significant at level 0.01.

Table III shows the associations between peak and relative power with the 10-m and 30-m sprints for different categories. For U15 athletes, a moderate and inverse association was observed between peak power and 30-m sprint ($r = -0.76$; $p=0.01$). For U17 athletes, small and moderate associations were observed between peak power and 10-m and 30-m sprints ($r = -0.37$; $p = 0.04$; $r = -0.55$; $p < 0.01$, respectively) and relative power with 10-m and 30-m sprints ($r = -0.42$; $p = 0.02$; $r = -0.56$; $p < 0.01$, respectively). Regarding the U20 athletes, it showed moderate and inverse associations between peak power ($r = -0.54$; $p = 0.02$) and relative power ($r = -0.62$; $p < 0, 01$) with the 10-m sprint. When all categories were observed, there was only a small and inverse correlation between peak power and 30-m sprint ($r = -0.32$; $p = 0.05$).

Table III – Correlation between power and sprint for different distance

	Peak Power x 10-m Sprint	Peak Power x 30-m Sprint	Relative Power x 10-m Sprint	Relative Power x 30-m Sprint
U 15	-0.53	-0.76**	-0.29	-0.58
U 17	-0.37*	-0.55*	-0.42*	-0.56*
U 20	-0.54*	-0.12	-0.62**	0.31
ALL	-0.18	-0.32*	-0.10	0.20

*Correlation was significant at level 0.05; **Correlation was significant at level 0.01.

Table IV shows the partial correlations between peak and relative power with 10-m and 30-m sprints controlled by FMS final score for different categories. Regarding the associations between peak power and 10-m and 30-m sprints in the U15 and U17, inverse and moderate correlations were observed ($r = -0.77$, $p = 0.02$; $r = - 0.54$, $p < 0.01$, respectively). For the U20, there was a moderate and inverse correlation between peak power and the 10-m sprint ($r = -0.56$; $p = 0.02$). When all players were analysed, a small association was found between peak power and 30-m sprint ($r = -0.32$; $p = 0.01$). According to the associations between relative power and the 30-m sprint, only a moderate and inverse correlation was observed in U17 category ($r = -0.52$; $p > 0.01$) and associations between relative power and the 10-m sprint in U20 ($r = -0.63$; $p > 0.01$). When all athletes were analysed no relationships were found.

Table IV – Correlation between power and sprint controlled by functional movement screen final score

		10-m Sprint	30-m Sprint
Peak Power	U-15	-0.58	-0.77*
(FMS Score)	U-17	-0.35	-0.54*
	U-20	-0.56*	-0.13
	All	-0.18	-0.32**
Relative Power	U-15	-0.49	-0.68
(FMS Score)	U-17	-0.36	-0.42**
	U-20	-0.63**	-0.29
	All	0.10	-0.19

*Correlation was significant at level 0.05; **Correlation was significant at level 0.01

Figure 1 shows the intra-group comparisons for performance variables involving different categories. No significant differences were observed when comparing athletes with FMS < 14 and > 14 in U15 category (peak power: $p = 0.98$, $t = -0.01$, $g = 0.009$; relative power: $p = 0.98$, $t = -0.02$, $g = 0.016$; 10-m sprint: $p = 0.15$, $t = -1.58$, $g = 0.994$; 30-m sprint: $p = 0.40$, $t = -0.89$, $g = 0.565$), U17 category (peak power: $p = 0.64$, $t = -0.47$, $g = 0.172$; relative power: $p = 0.12$, $t = -1.59$, $g = 0.578$; 10-m sprint: $p = 0.39$, $t = -0.13$, $g = 0.315$; 30-m sprint: $p = 0.14$, $t = -0.170$, $g = 0.539$), U20 category (peak power: $p = 0.92$, $t = -0.09$, $g = 0.043$; relative power: $p = 0.96$, $t = 0.04$, $g = 0.020$; 10-m sprint: $p = 0.69$, $t = -0,40$, $g = 0.184$; 30-m sprint: $p = 0.38$, $t = -0.89$, $g = 0.401$).

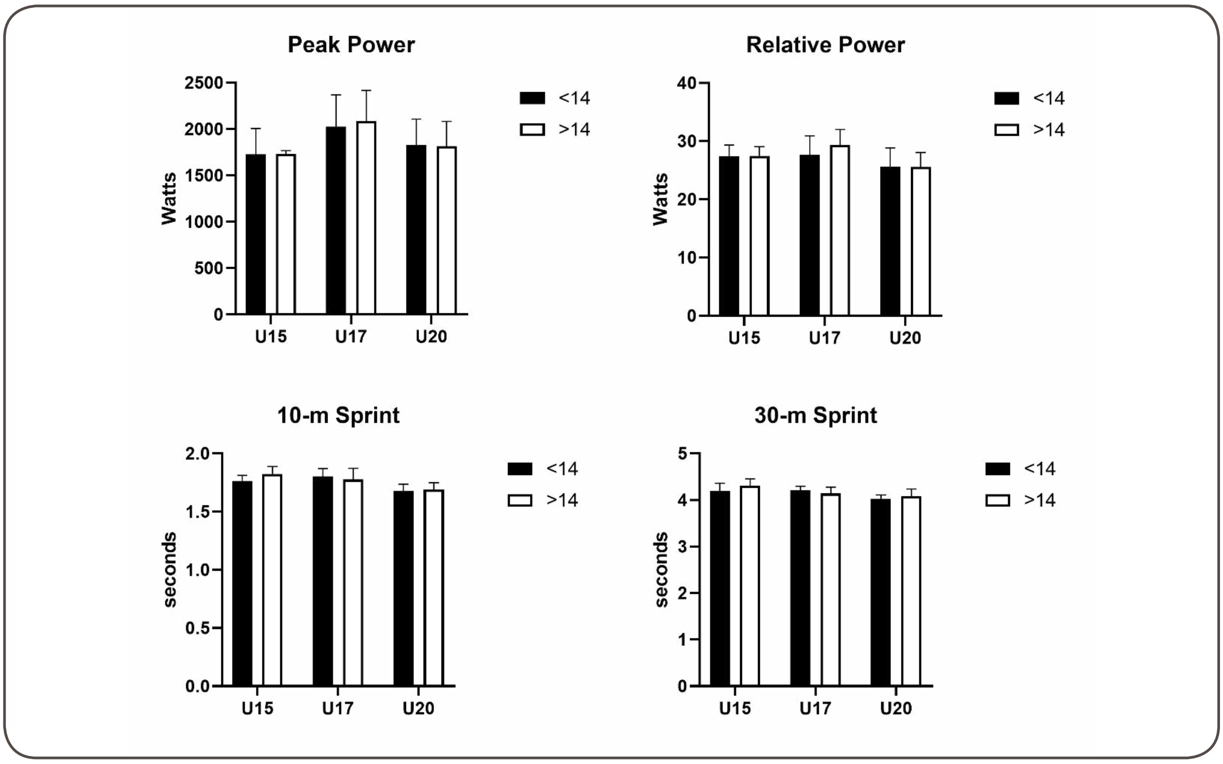

Figure 1 - Comparison of performance variables of U15, U17 and, U20 categories for groups of athletes with FMS <14 and >14

Discussion

The present study aimed to verify the relationship between FMS scores and performance variables in young elite soccer players of different categories. The main findings of this study are: trunk stability push-up presented small association with power capacity, as well as in line lunge with 10-m sprint. Peak power and 10-m sprint relationship were small in U17 and moderate in U20 players, and peak power relation with 30-m sprint were moderate in U15 and U17 players. Furthermore, moderate association were observed between relative power and 10-m and 30-m sprints in U17 and U20 players. In addition, the association was small when gathered the categories and FMS score did not change the relation between power and speed. Moreover, no differences were found in performance variables among athletes with FMS <14 and >14.

Regarding the individual FMS tests, trunk stability evaluated by Push-up and in line lunge showed a small relationship with the physical variables such as peak power, relative power, and speed in 10-m. These results can be explained by the fact that short distance speed (sprint 10 m) is highly related to quickly high force production (force development rate) in a horizontal direction vector. Although the in line lunge evaluates force on one leg, the vector is in the vertical direction, which may justify the small correlation [26,27]. A study of young soccer players showed that the morphology of the lumbar square and spine erector muscles both located on the trunk were a determining factor for improved sprinting ability over short distances [28]. This association can be explained mainly in short distances, acceleration phase, where athletes need to move the trunk forward to facilitate propulsion, according to electromyographic analysis, at these angles, there is high activation of the lumbar muscles [29,30]. Moreover, the present study found a small correlation ($r = -0.28$, $p = 0.03$) of in line lunge with 10-m sprint, although the small relationship, this movement pattern requires good upper body stability and strength of lower limbs in single-foot to support body weight [31].

Observing the relationship between physical variables and the final score of the FMS may be a way to notice associations between functional capacity and athletes' physical performance. The results found in this study corroborate previous studies with young soccer players which showed no associations between FMS final score and countermovement jump and squat jump [16,31]. The poor relation between FMS and performance in the analyzed variables can also be explained by the fact that in FMS it is necessary to obtain large ranges of motion and quality in movement, however in performance tests only the result is considered, not taking into account the movement quality. For example, in the deep squat test is required far range of motion and to keep the torso straight, but in the high-speed sprint for better acceleration in the early stages of the running, the athlete's torso need to be inclined projecting the center of mass [32].

The present research showed small association between power in pneumatic machine and speed while considered all categories. According to recent studies, improving the ability to generate lower limb power may be an effective way to promote speed increases in athletes [33,34]. It was expected that a relationship between peak power and speed within 10 meters would be found, as the ability to generate maximum force in a short time could assist in the body's removal of inertia at the start of the run and consequently increase acceleration [33]. Nevertheless, this result may have occurred since for some soccer athletes, the time to cover 10 m is not sufficient to develop the maximum power to accelerate the running [35]. Yet peak power and 30-m sprint presented moderate association in U15 and U17 categories, no association were found in U20 category. This can be explained by the different categories, the younger athletes may have a greater need for power to gain speed, owing to skills such as coordination, stretching and shortening cycle may not yet be developed [36].

The correlations of lower limb power controlled by FMS score and speed either at 10-m or at 30-m were unable to increase association. Thus, the levels of movement patterns in athletes did not change this relationship between power and speed. However, the good movement patterns in specific skills can reduce asymmetries by favoring muscle synergy and it can also expose athletes to lower injury risk factors which increases players competitive time [37]. The adequate usage of limb power to improve acceleration is explained by the ability to perform motions with a balance between mobility and stability along the kinetic chain, which prevents energy dissipation, favoring skill accuracy [31]. Regarding comparisons involving athletes with FMS scores < 14 and > 14, there was no difference for any physical variable analysed in the present study, for all categories. These outcomes corroborate the findings in the current literature that show that the value of 14 in FMS result cannot be considered a good parameter to discriminate athletes [23].

The study has some limitations: 1) initially, the maturational state of the athletes was not considered, which might interfere in physical performance; 2) second, lower limb power rating used load with arbitrary values. Nevertheless, the study has some strengths: 1) it is the first study to use the relationship between power and speed using pneumatic machines; 2) the sample has athletes from different categories. Therefore, these conclusions can assist coaches to plan training sessions for direct the development of relevant aspects to improve athletes' performance and suggesting coaches seek strategies to assess movement patterns of specific skills. Moreover, future research should be performed using power tests that use the individual's loads for understand the power x speed profile, plus a longitudinal study to see if young athletes who have lower FMS scores suffer a greater number of injuries over time. In addition, new researches must observe cut off points of FMS score considering the characteristics of the studied sample.

Conclusion

Based on the findings of the present study, it can be assumed that there are no association between FMS final score and physical variables in youth soccer athletes. However, trunk stability and in line lunge assessed by FMS have demonstrated a small association with performance. Moreover, relationship between power in pneumatic test and speed were moderate and this relation did not change when controlled by FMS score. In addition, the score of 14 shows to be a weak cut-off value, as it did not show differences in the physical variables.

Conflict of interest
The authors have no conflict of interest directly relevant to the contents of this article.

Funding
This research was partially supported by grants from the Carlos Chagas Filho Foundation for the Research Support in Rio de Janeiro State and Brazilian Council for the Technological and Scientific Development and was financed in part by the Coordenação de Aperfeiçoamento Pessoal de Nivel Superior–Brasil (CAPES)–Finance Code 001

Authors' contribution
Diêgo Augusto was responsible for developing the research problem and writing the article. Fabio Eiras performed the data collection. Deborah Touguinhó and Maria Juliana assisted in writing. Fabrício Vasconcellos guided the whole process.

References

1. Bangsbo J. Energy demands in competitive soccer. J Sports Sci 1994;12:5-12. doi: 10.1080/02640414.1994.12059272

2. Bangsbo J, Iaia F, Krustrup P. Metabolic response and fatigue in soccer. Int J Sports Physiol Perform 2007;2(2):111-27. doi: 10.1123/ijspp.2.2.111

3. Bangsbo J, Mohr M, Krustrup P. Physical and metabolic demands of training and match-play in the elite football player. J Sports Sci 2006;24:665-74. doi: 10.1080/02640410500482529

4. Krustrup P, Mohr M, Steensberg A, Bencke J, Kjaer M, Bangsbo J. Muscle and blood metabolites during a soccer game: implications for *sprint* performance. Med Sci Sports Exerc 2006;38(6):1165-74. doi: 10.1249/01.mss.0000222845.89262.cd

5. Faude O, Koch T, Meyer T. Straight *sprint*ing is the most frequent action in goal situations in professional football. J Sports Sci 2012;30(7):625-31. doi: 10.1080/02640414.2012.665940

6. Kobal R, Loturco I, Barroso R, Gil S, Cuniyochi Rr, Ugrinowitsch C, *et al*. Effects of different combinations of strength, power, and plyometric training on the physical performance of elite young soccer players. J Strength Cond Res 2017;31(6):1468-76. doi: 10.1519/JSC.0000000000001609

7. Bennett H, Davison K, Arnold J, Slattery F, Martin M, Norton K. Multicomponent musculoskeletal movement assessment tools: a systematic review and critical appraisal of their development and applicability to professional practice. J Strength Cond Res 2017;31(10):2903-19. doi: 10.1519/JSC.0000000000002058

8. Campa F, Spiga F, Toselli S. The effect of a 20-week corrective exercise program on functional movement patterns in youth elite male soccer players. J Sport Rehabil 2019;28(7):746-51. doi: 10.1123/jsr.2018-0039

9. Walker S, Turner A. A one-day field test battery for the assessment of aerobic capacity, anaerobic capacity, speed, and agility of soccer players. J Strength Cond Res 2009;31(6):52-60. doi: 10.1519/SSC.0b013e3181c22085

10. Hulse MA, Morris JG, Hawkins RD, Hodson A, Nevill AM, Nevill ME. A field-test battery for elite, young soccer players. Int J Sports Exerc Med 2013;34(04):302-11. doi: 10.1055/s-0032-1312603

11. Loturco I, D'Angelo RA, Fernandes V, Gil S, Kobal R, Abad CCC, *et al.* Relationship between *sprint* ability and loaded/unloaded jump tests in elite *sprin*ters. J Strength Cond Res 2015;29(3):758-64. doi: 10.1519/JSC.0000000000000660

12. Zabaloy S, Carlos-Vivas J, Freitas TsT, Pareja-Blanco F, Pereira L, Loturco I, *et al.* Relationships between resisted *sprint* performance and different strength and power measures in rugby players. Sports 2020;8(3):34. doi: 10.3390/sports8030034

13. Frost DM, Cronin JB, Newton RU. A comparison of the kinematics, kinetics and muscle activity between pneumatic and free weight resistance. Eur J Appl Physiol 2008;104(6):937-56. doi: 10.1007/s00421-008-0821-8

14. Frost DM, Bronson S, Cronin JB, Newton RU. Changes in maximal strength, velocity, and power after 8 weeks of training with pneumatic or free weight resistance. J Strength Cond Res 2016;30(4):934-44. doi: 10.1519/JSC.0000000000001179

15. Maior A. Absolute and relative peak power during pneumatic squat exercise using different percentages of loads in elite soccer players. Hum Mov 2020;21(3):64-70. doi: 10.5114/hm.2020.91347

16. Silva B, Clemente FM, Camões M, Bezerra P. Functional movement screen scores and physical performance among youth elite soccer players. Sports 2017;5(1):16. doi: 10.3390/sports5010016

17. Silva B, Clemente FM, Martins FM. Associations between functional movement screen scores and performance variables in surf athletes. J Sports Med Phys Fitness 2018;58(5):583-90. doi: 10.23736/S0022-4707.17.07154-7

18. Lloyd RS, Oliver JL, Radnor JM, Rhodes BC, Faigenbaum AD, Myer GD. Relationships between functional movement screen scores, maturation and physical performance in young soccer players. J Sports Sci 2015;33(1):11-9. doi: 10.1080/02640414.2014.918642

19. Cook G, Burton L, Hoogenboom B. Pre-participation screening: the use of fundamental movements as an assessment of function-part 1. N Am J Sports Phys Ther [Internet] 2006;1(2):62-72. [citado 2021 May 10]. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2953313/

20. Cook G, Burton L, Hoogenboom B. Pre-participation screening: the use of fundamental movements as an assessment of function-part 2. N Am J Sports Phys Ther [Internet] 2006;1(3):132-9. [citado 2021 May 10]. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2953359/

21. Hammes D, Funten K Aus der, Bizzini M, Meyer T. Injury prediction in veteran football players using the Functional Movement Screen™. J Sports Sci 2016;34(14):1371-9. doi: 10.1080/02640414.2016.1152390

22. Cuchna JW, Hoch MC, Hoch JM. The interrater and intrarater reliability of the functional movement screen: a systematic review with meta-analysis. Phys Ther Sport 2016;19:57-65. doi: 10.1016/j.ptsp.2015.12.002

23. Moore E, Chalmers S, Milanese S, Fuller JT. Factors influencing the relationship between the functional movement screen and injury risk in sporting populations: a systematic review and meta-analysis. Sports Med 2019:1-15. doi: 10.1007/s40279-019-01126-5

24. Lee S, Kim H, Kim J. The functional movement screen total score and physical performance in elite male collegiate soccer players. J Exerc Rehabil 2019;15(5):657-62. doi: 10.12965/jer.1938422.211

25. Cohen J. Statistical power analysis for the behavioral sciences (2ª ed). Hillsdale: Erbaum Press; 1988. doi: 10.4324/9780203771587

26. Bezodis NE, North JS, Razavet JL. Alterations to the orientation of the ground reaction force vector affect *sprint* acceleration performance in team sports athletes. J Sports Sci 2017;35(18):1817–24. doi: 10.1080/02640414.2016.1239024

27. Hicks DS, Schuster JG, Samozino P, Morin J-B. Improving mechanical effectiveness during *sprint* acceleration: practical recommendations and guidelines. Strength Cond J 2019;1. doi: 10.1519/SSC.0000000000000519

28. Kubo T, Hoshikawa Y, Muramatsu M, Iida T, Komori S, Shibukawa K, *et al.* Contribution of trunk muscularity on *sprint* run. Int J Sports Med 2011;32(03):223-8. doi: 10.1055/s-0030-1268502

29. Thorstensson ALF, Carlson H, Zomlefer MR, Nilsson J. Lumbar back muscle activity in relation to trunk movements during locomotion in man. Acta Physiol Scand 1982;116(1):13-20. doi: 10.1111/j.1748-1716.1982.tb10593.x

30. Thorstensson ALF, Nilsson J, Carlson H, Zomlefer MR. Trunk movements in human locomotion. Acta Physiol Scand 1984;121(1):9-22. doi: 10.1111/j.1748-1716.1984.tb10452.x

31. Okada T, Huxel KC, Nesser TW. Relationship between core stability, functional movement, and performance. J Strength Cond Res 2011;25(1):252-61. doi: 10.1519/JSC.0b013e3181b22b3e

32. Moir GL. Biomechanics of fundamental movements: Sprint running. Strength and conditioning: a biomechanical approach. Burlington, MA: Jones & Bartlett Learning; 2016. p.523-74. Available from: http://samples.jblearning.com/9781284034844/FrontMatter.pdf

33. Loturco I, Contreras B, Kobal R, Fernandes V, Moura N, Siqueira F, *et al.* Vertically and horizontally directed muscle power exercises: Relationships with top-level *sprint* performance. PLoS One 2018;13(7). doi: 10.1371/journal.pone.0201475

34. Loturco I, Nakamura F, Kobal R, Gil S, Abad Cs, Cuniyochi Rr, *et al.* Training for power and speed: Effects of increasing or decreasing jump squat velocity in elite young soccer players. J Strength Cond Res 2015;29(10):2771-9. doi: 10.1519/JSC.0000000000000951

35. Moura F, Marche AL, Caetano FG, Torres RDS, Martins LEB, Cunha SA. Analysis of high-intensity efforts in Brazilian professional soccer players. Hum Mov 2017;18(5):55-62. doi: 10.1515/humo-2017-0043

36. Rommers N, Mostaert M, Goossens L, Vaeyens R, Witvrouw E, Lenoir M, *et al.* Age and maturity related differences in motor coordination among male elite youth soccer players. J Sports Sci 2019;37(2):196-203. doi: 10.1080/02640414.2018.1488454

37. Kiesel K, Plisky P, Butler R. Functional movement test scores improve following a standardized off-season intervention program in professional football players. Scand J Med Sci Sports 2011;21(2):287-92. doi: 10.1111/j.1600-0838.2009.01038.x