INFLUENCE OF MAXIMAL ISOMETRIC STRENGTH ON 20-METER SPRINT TIME

INFLUÊNCIA DA FORÇA ISOMÉTRICA MÁXIMA SOBRE O TEMPO EM SPRINTS DE 20 METROS

INFLUENCIA DE LA FUERZA ISOMÉTRICA MÁXIMA SOBRE EL TIEMPO EN SPRINTS DE 20 METROS

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ABSTRACT

Introduction: The squat is an exercise that is widely used for the development of strength in sports. However, considering that not all sports gestures are vertical, it is important to investigate the effectiveness of propulsive force stimuli applied in different planes. Objective: The main purpose of this study was to determine the influence of maximum isometric force (MIF) exerted on starting blocks over performance in 5, 10 and 20-meter sprints. Methods: Seven high-level male sprinters (mean age ± SD = 28 ± 5.77 years) participated in this study. The variables were: a) MIF in squats and on starting blocks (measured using a functional electromechanical dynamometer [FEMD]), b) time in 5, 10 and 20-m sprints and c) jump height (measured by the squat jump test). For data analysis, a Pearson correlation was performed between the different variables. The criteria for interpreting the strength of the r coefficients were as follows: trivial (<0.1), small (0.1–0.3), moderate (0.3–0.5), high (0.5–0.7), very high (0.7–0.9), or practically perfect (>0.9). The level of significance was $p < 0.05$. Results: There was very high correlation between MIF exerted on starting blocks and performance in the first meters of the sprint (5-m: $r = -0.84$, $p = 0.01$). However, there was small correlation between MIF in squats and performance in the first meters of the sprint (5-m: $r = -0.22$, $p < 0.62$). Conclusion: The MIF applied on starting blocks correlates very high with time in the first meters of the sprint in high-level athletes. In addition, the use of the FEMD provides a wide range of possibilities for evaluation and development of strength with a controlled natural movement. ***Level of evidence IV; Prognostic Studies - Case series.***

Keywords: Muscle strength; Isometric contraction; Athletes.

RESUMO

Introdução: O agachamento é um exercício amplamente utilizado para o desenvolvimento de força nos esportes. No entanto, considerando que nem todos os gestos esportivos são verticais, é importante investigar a eficácia dos estímulos de força propulsiva em diferentes planos. Objetivo: O principal objetivo deste estudo foi determinar a influência da força isométrica máxima (FIM) exercida em os blocos de largada sobre o desempenho em sprints *de 5, 10 e 20 metros. Métodos: Sete velocistas de alto nível do sexo masculino (média ± DP = 28,0 ± 5,77 anos) fizeram parte deste estudo. As variáveis foram: a) FIM no agachamento e nos blocos de largada (avaliados com um dinamômetro eletromecânico funcional (DEF)), b) tempo de* sprints *de 5, 10 e 20 metros e c) altura do salto (medida pelo teste de squat jump). Para análise dos dados, foi usada a correlação de Pearson entre as diferentes variáveis. Os critérios para interpretar o coeficiente r foi: nulo (< 0,1), pequeno (0,1 a 0,3), moderado (0,3 a 0,5), alto (0,5 a 0,7), muito alto (0,7 a 0,9) ou praticamente perfeito (> 0,9). O nível de significância foi p < 0,05. Resultados: Houve correlação muito alta entre a FIM exercida nos blocos de largada e o desempenho nos primeiros metros do* sprint *(5-m: r = -0,84, p = 0,01). No entanto, a correlação entre o agachamento da FIM e os primeiros metros de sprint foi pequena (5-m: r = -0,22, p < 0,62). Conclusão: A FIM aplicada aos blocos de largada teve uma correlação muito alto com o tempo nos primeiros metros de* sprint *em atletas de alto nível. Além disso, o uso de um DEF oferece uma ampla gama de possibilidades para avaliar e desenvolver força com um movimento natural controlado.* ***Nível de evidência IV; Estudos Prognósticos – Série de casos.***

Descritores: *Força muscular; Contração isométrica; Atletas.*

RESUMEN

Introducción: La sentadilla es un ejercicio ampliamente usado para el desarrollo de fuerza en los deportes. Sin embargo, considerando que no todos los gestos deportivos son verticales, es importante investigar la eficacia de los estímulos de fuerza propulsiva en diferentes planos. Objetivo: El principal objetivo de este estudio fue determinar la influencia de la fuerza isométrica máxima (FIM) ejercida en los bloques de salida sobre el rendimiento en sprints de 5, 10 y 20 metros. Métodos: Siete velocistas de alto nivel del sexo masculino (promedio ± SD = 28,0 ± 5,7 años) formaron parte de este estudio. Las variables fueron: a) FIM en la sentadilla y en los bloques de salida (evaluados con un dinamómetro electromecánico funcional [DEF]) b) tiempo de sprints *de 5, 10 y 20-metros y c) altura del salto (medida a través del test de squat jump). Para el análisis de los datos se usó la correlación de Pearson entre las diferentes variables. Los criterios para interpretar el coeficiente r fueron: nulo (<0,1), pequeño (0,1 a 0,3), moderado (0,3 a 0,5), alto (0,5 a 0,7), muy alto (0,7 a 0,9) o prácticamente perfecto (>0,9). El nivel de significancia fue p < 0,05. Resultados: Hubo correlación muy alta entre* *la FIM ejercida en los bloques de salida y el rendimiento en los primeros metros del* sprint *(5-m: r = -0,84, p = 0,01). Sin embargo, la correlación entre la FIM en sentadilla y los primeros metros de* sprint *fue pequeña (5-m: r = -0,22, p < 0,62). Conclusión: La FIM aplicada a los bloques de salida tuvo una correlación muy alta con el tiempo en los primeros metros de* sprint *en atletas de alto nivel. Además, el uso de un DEF ofrece una amplia gama de posibilidades para evaluar y desarrollar fuerza con un movimiento natural controlado.* ***Nivel de evidencia IV; Estudios pronósticos: Serie de casos.***

Descriptores: *Fuerza muscular; Contracción Isométrica; Atletas.*

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INTRODUCTION

Back squat is a widely used exercise for the development of strength in sports[1,2] which increases force levels in the lower extremities.[2,3] However, some studies emphasize that not all sports gestures are vertical;[1,2] these studies evidence that some trainings are more effective than squats for strength development in the lower-body, concluding that the effectiveness of the stimulus may be conditioned to the vector planes of the propulsive force.[4]

In relation to the increase in performance in velocity athletic tests, different training methodologies have been used.[2,5] However, and under the vector parameters of force application, most of these investigations have applied nonspecific exercises when compared to real sports movements.[6] While there is a transference from the vertical forces developed through squats towards horizontal forces (sprint performance),[2,3] it is also important to analyze studies that have reported a decrease in the magnitude of correlations between vertical and horizontal forces in high-level athletes.[7]

Currently, there are several tools for evaluating strength and speed.[8,9] However, the assessment and training of strength in sprinters should be similar to the gestures developed in competitions.[7] For example, sprinters should consider force assessments on starting blocks.

According to the characteristics of the sprinters and the specificity of the start from starting blocks, it seems that a quick start off is a key factor for the performance in the first 20 meters (20-m) of sprint.[10] However, the maximal isometric force (MIF) on starting blocks and its relation to performance in the first few meters of the sprint has not been evaluated.[10] To help with these relation, there are functional electromechanical dynamometers (FEMDs) that allow to execute evaluation in similar conditions from competition, specifically in vector planes and muscular contractions.[11]

Considering that the isometric force is present during the "set" position on starting blocks and that, nowadays, there are devices that allow quantifying the strength exerted in different vector planes, the primary aim of this study was to determine the influence of MIF on starting blocks over time performance in 5, 10 and 20-m sprints. The secondary objectives were to relate the MIF exerted on starting blocks to the height of jump. In addition, the hypothesis of this study was that there is a high relation between the MIF exerted on starting blocks and time performance in 20-m sprints.

METHODS

Experimental approach to the problem

This was a quantitative research with a pre-experimental design. The inclusion criterion was previous performance in 100-m sprint tests (during the 2019 season, athletes had to reach a run time of less than 10.95 seconds [s] in the 100-m sprint). Exclusion criteria were: the prevalence of musculoskeletal injuries, the inability to perform maximum isometric tests, the inability to perform start from starting blocks or the inability to perform SJ tests.

Participants

Seven high-level male sprinters volunteered to participate in this study. (Table 1) All participating athletes and coaches were informed of the objectives of the study and the possible risks of the experiment. In addition, they signed an informed consent prior to the application of the protocol. Both, the study protocol and the informed consent were approved by the Human Research Ethics Committee of the University of Granada, Spain (registry 493/CEIH/2019) and conformed to the standards of the latest revision of the Declaration of Helsinki.

Testing protocol

Evaluation day 1: after the warm-up, the subjects performed four exercise modalities with maximal isometric contractions of the lower--body: I) isometric squat with knee flexion at 90°. In this execution, the lateral separation of the feet was the projection of the width of the shoulders towards the floor (both soles were supported, the back was straight and the hands were laying on the hips). (Figure 1A) II) Isometric squat with dominant knee forward and flexed at 90°. In this test, the anteroposterior separation of the feet was 1 cm between the heel of the forefoot and the tip of the delayed foot. The measurement of the angle of 90º was executed in the knee of the forefoot, while the lateral

Table 1. Characteristics of the sample (mean ± SD).

Participants	Age (years)	Dominant foot	Best record in 100-m (s)	Experience (years)	Weight (Kg)	Body Mass (m)	BMI (kg/m²)	Body fat (%)	MIFS/BM
a	25	Left	10.94	16	76.4	1.88	21.6	6.1	0.73
b	24	Left	10.94	10	74.6	1.78	23.5	11.1	1.54
c	26	Right	10.49	5	88.4	1.90	24.5	8.5	0.95
d	24	Right	10.31	9	71.5	1.80	22.1	6.9	1.00
e	39	Left	10.92	25	71.4	1.74	23.7	10.4	0.98
f	33	Right	10.62	20	74.3	1.81	22.7	7.5	1.52
g	25	Right	10.90	10	79.8	1.71	27.3	12.5	1.18
mean	28.0	------	10.73	13.6	76.6	1.80	23.6	9.0	1.13
SD	5.77	------	0.26	7.04	5.94	0.07	1.89	2.38	0.30

Seconds (s), kilograms (Kg), meters (m): body mass index (BMI), maximal isometric force in squat (MIFS), body mass (BM), standard deviation (SD).

Figure 1. Evaluation of maximal isometric forces. Isometric squat with knee flexion at 90° (A), isometric squat with dominant knee forward and flexed at 90° (B), maximal isometric force of the lower-body exerted on starting blocks with dominant knee forward and flexed at 90° (C), maximal isometric force of the lower-body exerted on starting blocks with both knees at 90º (D).

separation of the feet was the projection of the width of shoulders towards the floor. In this execution, the forefoot supported the whole sole while the delayed foot only supported the metatarsal (straight back and hands laying on hips). (Figure 1B) III) MIF of the lower-body exerted on starting blocks with dominant knee forward and flexed at 90°, delayed knee flexed at 130°. In this test, the lateral separation of the feet was given by the structure of the starting blocks. In this execution both soles rested on the entire surface of the starting blocks, the back was straight and hands never lost contact with the floor ("set" position). (Figure 1C) IV) MIF of the lower-body exerted on starting blocks with both knees at 90º, the lateral separation of the feet was given by the structure of the starting blocks. In this test, both soles were supported on the entire surface of the starting blocks, the back was straight and the hands never lost contact with the floor ("set" position). (Figure 1D)

The MIF for the four modalities was evaluated for 5 s[12] with a FEMD (Dynasystem®, Symotech, Granada, Spain). The FEMD allows kinetic-tonic control of the movement (0.10–1.5 $m \cdot s^{-1}$) and isometric assessment of muscle strength (5–3000 N) with a sampling frequency of 1.000 Hz (Dynasystem, Model Research, Granada, Spain).[11] The MIF, expressed in newtons, was recorded and used in the subsequent statistical analysis. The order of the exercises was cross-referenced for the entire sample.

Evaluation day 2: after the warm-up, in the 20-m sprint, the time was measured in milliseconds (ms) from the starting on starting blocks; for the statistical analysis, it was considered the time performance (ms) from the starting block until 5, 10 and 20 m of the sprint. The evaluation was performed using a photoelectric cell (Microgate® model Polifemo SF Radio, Bolzano, Italy) with a radius transmission range of approximately 2 km and a reflective operation with a range of more than 35 m in an athletics track. For the starts from the starting blocks, there were used audible athletic competition signals: "on your marks", "set" and the sound of a starting gunfire. Starting blocks were Polanik® (Piotrków Trybunalski, Poland).

Squat Jumps were measured in cm from a bipodal position, with knees angled at 90º, hands on hips and no countermovement.[13] The evaluation was carried out using a jumping mat (Optojump®, Bolzano, Italy). The carpet contains 96 infrared LEDs (1.0416 cm resolution). These LEDs are located on the transmitting bar and communicate continuously with the LEDs located on the receiving bar. The system detects interruptions and their duration. The order of the exercises was cross-referenced for the entire sample.

Statistical analysis

The variables were analyzed in the Shapiro–Wilk normality test. Then, a Pearson correlation analysis was performed between the different maximal isometric exercises and time performance in 5, 10 and 20-m sprints. The level of significance for all statistical analyses was $p < 0.05$.

RESULTS

The descriptive characteristics of jumping heights in SJ tests and time performance in 5, 10 and 20-m sprints are presented in Table 2. In addition, the absolute and relative values (peak and mean) for the four modalities of MIF (2 in squat and 2 on starting blocks) are shown in Table 3.

The Pearson's test showed a very high correlation between SJ tests and the 100-m personal best mark reported by sprinters (r = -0.88, p = 0.007). (Table 4) On the other hand, low correlations were obtained in the absolute maximal isometric squat and the first meters of sprint (absolute peak values and 5-m sprint: r = -0.22, p = 0.62; absolute mean values and 5-m sprint: r = -0.33, p = 0.45). (Table 4 and Figure 2A) Likewise, very low correlation were obtained between the relative maximal isometric squat and the first meters of sprint (relative peak values and 5-m sprint: r = -0.08, p = 0.85; relative mean values and 5-m sprint: r = -0.21, p = 0.64). (Table 4 and Figure 2B)

The Pearson's test showed a moderate correlation between absolute isometric squat, with dominant knee forward and flexed at 90°, and the first meters of sprint (absolute peak values and 5-m sprint: r = -0.65, p = 0.11; absolute mean values and 5-m sprint: r = -0.65, p = 0.25). (Table 4 and Figure 2C) Likewise, high correlation were obtained in the relative isometric squat, with dominant knee forward and flexed at 90°, and the first meters of sprint (relative peak values and 5-m sprint: r = -0.49, p = 0.25; relative mean values and 5-m sprint: r = -0.53, p = 0.21). (Table 4 and Figure 2D)

On the other hand, the Pearson's test showed a moderate correlation between the absolute MIF of the lower-body exerted on starting blocks, with dominant knee forward and flexed at 90°, and the first 5-m sprint (r = -0.70, p = 0.07). (Table 4 and Figure 2E-F) In addition, there was a moderate correlation between the absolute MIF of the lower-body exerted on starting blocks, with dominant knee forward and flexed at 90°, and the first 10 and 20-m sprint (10 m: r = -0.48, p = 0.27; 20 m: r = -0.46, p = 0.29). (Table 4)

The Pearson's test showed a high correlation between absolute MIF of the lower-body exerted on starting blocks, with both knees at 90º, and the first 5-m sprint (absolute peak values and 5-m sprint: r = -0.84, p = 0.01; absolute mean values and 5-m sprint: r = -0.82, p = 0.02). (Table 4 and Figure 2G) In addition, there was a very high correlation between the relative MIF of the lower-body exerted on starting blocks, with both knees at 90º, and the first 5-m sprint (relative peak values and 5-m sprint: r = -0.76, p = 0.04; relative mean values and 5-m sprint: r = -0.74, p = 0.05). (Table 4 and Figure 2H)

Table 2. Squat jump and run values in 5, 10 and 20-m sprints.

Participants	SJ (cm)	5-m sprint (ms)	10-m sprint (ms)	20-m sprint (ms)
a	42.8	1070	1755	2905
b	46.6	1085	1775	2965
c	53.5	995	1650	2785
d	56.5	1025	1715	2875
e	46.7	1070	1735	2960
f	46.3	971	1624	2755
g	41.8	985	1763	3038
mean	47.7	1028	1716	2897
SD	5.38	46	58	101

SJ (Squat Jump), centimeters (cm), milliseconds (ms), standard deviation (SD).

Table 3. Maximal isometric force values in squat and starting blocks (absolute and relative).

Participants	Isometric squat (both knees flexed at 90°)				Isometric squat (dominant knee forward and flexed at 90°)				Starting blocks (dominant knee forward and flexed at 90°)				Starting blocks (both knees flexed at 90º)			
	absolute (N)		relative (N)		absolute (N)		relative (N)		absolute (N)		relative (N)		absolute (N)		relative (N)	
	peak force	mean force	peak force	mean force	peak force	mean force	peak force	mean force	peak force	mean force	peak force	mean force	peak force	mean force	peak force	mean force
a	734.0	547.5	9.607	7.166	566.0	482.9	7.408	6.320	763,5	675.4	9.993	8.831	483.0	450.8	6.321	5.898
b	1256.0	1122.8	16.836	15.052	868.0	770.5	11.635	10.329	712,0	622.1	9.537	8.33	520.0	470.5	6.970	6.306
c	933.0	826.9	10.554	9.354	841.0	712.4	9.513	8.059	789,0	706.7	9.375	7.994	612.0	549.2	6.923	6.208
d	789.0	699.9	11.034	9.788	699.0	605.8	9.776	8.472	741,0	615.9	10.363	8.614	469.5	435.7	6.566	6.093
e	744.0	685.3	10.42	9.598	808.0	706.2	11.316	9.891	615,5	550.6	8.620	7.710	461.0	443.1	6.456	6.185
f	1142.0	1105.5	15.37	14.879	1142.0	1083.6	15.37	14.584	803,0	708.7	10.498	9.526	784.0	719.1	10.552	9.687
g	1016.0	924.1	12.732	11.580	968.0	916.3	12.13	11.482	724,0	688.6	9.073	8.629	783.0	747.5	9.812	9.367
mean	944.8	844.6	12.365	11.059	841.7	753.9	11.021	9.877	735,4	652.6	9.637	8.519	587.5	545.1	7.657	7.106
SD	204.1	218.5	2.756	2.961	184.5	197.7	2.499	2.672	62,3	58.5	0.686	0.591	143	134.2	1.753	1.66

Newton (N).

Table 4. Correlations between maximal isometric force variables and first meters of sprint (n = 7).

Pearson Correlation		5-m sprint	10-m sprint	20-m sprint	100-m sprint
SJ	r	-0.129	-0.432	-0.504	-0.886**
Isometric squat (both knees flexed at 90°) Absolute peak values	r	-0.228	-0.105	-0.051	0.131
Isometric squat (both knees flexed at 90°) Absolute mean values	r	-0.337	-0.224	-0.106	0.046
Isometric squat (both knees flexed at 90°) Relative peak values	r	-0.085	-0.019	0.009	0.167
Isometric squat (both knees flexed at 90°) Relative mean values	r	-0.214	-0.151	-0.056	0.077
Isometric squat (dominant knee forward and flexed at 90°) Absolute peak values	r	-0.653	-0.486	-0.215	-0.036
Isometric squat (dominant knee forward and flexed at 90°) Absolute mean values	r	-0.659	-0.438	-0.166	0.003
Isometric squat (dominant knee forward and flexed at 90°) Relative peak values	r	-0.496	-0.396	-0.153	0.005
Isometric squat (dominant knee forward and flexed at 90°) Relative mean values	r	-0.531	-0.372	-0.125	0.031
Starting blocks (dominant knee forward and flexed at 90°) Absolute peak values	r	-0.228	-0.105	-0.051	0.131
Starting blocks (dominant knee forward and flexed at 90°) Absolute mean values	r	-0.703	-0.481	-0.461	-0.205
Starting blocks (dominant knee forward and flexed at 90°) Relative peak values	r	-0.270	-0.418	-0.613	-0.538
Starting blocks (dominant knee forward and flexed at 90°) Relative mean values	r	-0.465	-0.325	-0.367	-0.146
Starting blocks (both knees flexed at 90°) Absolute peak values	r	-0.842*	-0.416	-0.159	-0.021
Starting blocks both knees flexed at 90°) Absolute mean values	r	-0.826*	-0.355	-0.079	0.025
Starting blocks (both knees flexed at 90°) Relative peak values	r	-0.768*	-0.376	-0.125	0.01
Starting blocks (both knees flexed at 90°) Relative mean values	r	-0.748	-0.314	-0.046	0.056

Correlation is significant at level 0.01 (**), correlation is significant at level 0.05 (*).

DISCUSSION

The main results of this study indicate that there is a high correlation between the MIF exerted on starting blocks and time in a 5-m sprint in high-level male sprinters ($r = -0.70$, $p = 0.07$). In recent studies similar correlation have been obtained between lower-body strength and sprinting time performances.[14,15] For example, the study of Andersen et al.[14] showed a high correlation between relative lower-body strength and 10-m and 30-m sprints in collegiate women soccer players ($r = -0.59$, $p < 0.05$ and $r = -0.67$, $p < 0.01$, respectively); these authors concluded that relative lower-body strength is important since it improves power, agility, and speed performance. Likewise, the study of McBride et al.[15] showed a moderate correlation between relative maximal squat strength (1RM/body mass) and performance in 5 and 10 yards ($r = -0.45$, $p = 0.06$ and $r = -0.54$, $p = 0.02$, respectively). They concluded that the level of strength of the lower-body musculature, in male football athletes, is an obvious site of interest for maximizing sprinting ability.

In a study of Janowski et al.,[10] it was aimed to evaluate individual kinematic characteristics in highly trained sprinters during the "set" position, block clearance and a 20-m acceleration phase; it was concluded that fast block clearance and stride symmetry are key factors affecting sprint performance during the 20-m acceleration phase. Despite these results, it is important to mention that rapid clearance not always mean that high levels of force or power are being exerted on starting blocks. In this sense, as previous researches on controlled natural movements,[16] the use of the FEMDs made possible to cover non explored areas and generate knowledge applicable to sprinters, based on its isometric mode.

A relevant piece of information resulting from this research was the low correlation between the MIF in squat and the first meters of a sprint (5-m: $r = -0.22$, $p = 0.64$; 10-m: $r = -0.15$, $p < 0.74$; 20-m: $r = -0.05$, $p = 0.86$). Possibly, the low correlations observed between squats and sprints are due to horizontal plans and vertical plans in the application of force, respectively; this suggests that the two tasks provide distinctive information regarding the force-velocity--power profile of lower-body muscles, especially in high-level sprinters and high-level athletes.[7] Therefore, a key element to increase sport performance is determining the specific vector parameters for each sport reality.[4,6]

There are studies that have connected a higher jumping height with the force levels of the lower extremities.[3] For example, Andersen et al.[14] reported a high correlation between the relative lower-body strength and the vertical jump in collegiate women soccer players ($r = 0.54$, $p < 0.05$); this authors concluded that the development of absolute and relative lower-body strength should be emphasized to increase speed performance. An important investigation for the comparison of results, due to the similarities to our study, is Carmona et al.;[17] these researchers calculated a correlation of -0.925 ($p > 0.05$) for the SJ and the 30-m sprint in female sprinters, concluding that the maximum speed is the main parameter

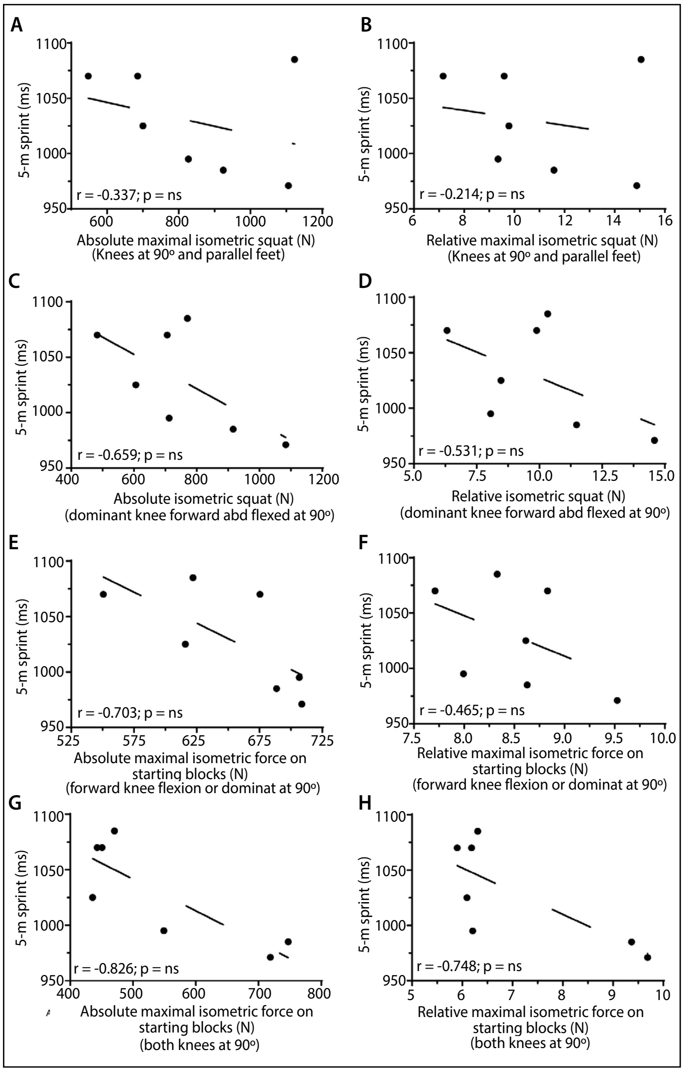

Figure 2. Relation between the maximal isometric forces and performance in 5-meter sprints. Newton (N), milliseconds (ms), ns (not significant).

of performance in this population. However, in the present study, one of the analyses correlated were SJ and MIF exerted on starting blocks (dominant knee forward and flexed at 90°); at the end of the analysis, a very low correlation between both variables were evidenced (r = -0.14; p = 0.75). This result was similar to the one performed between the MIF in squat and time in the first meters of sprint (5-m: r = -0.22, p = 0.64; 10-m: r = -0.15, p < 0.74; 20-m: r = -0.05, p = 0.90). With the information described above it can be concluded that the jump and sprint tests have different values (horizontal vector and vertical vector); however, they complement each other to establish the force-velocity-power profile for each athlete.[7]

Both, the type of muscular contraction (MIF) and the sport-specific vector planes (starting blocks in sprinters) could be evaluated using DEMFs. These devices allowed the evaluation of force in similar conditions to competition, specifically in vector planes and muscular contractions.[11] Therefore, the use of DEMFs is suggested, not only in rehabilitation,[11,18] but in all the realities of controlled natural motion.

CONCLUSION

In conclusion, at the end of the study it was possible to determine that the MIF on starting blocks has a high correlation over time performance in 5-m sprints. For this reason, it is concluded that high-levels of MIF have a positive influence on performance in the first meters of a sprint in high-level athletes, starting from the starting blocks.

Even though there are small correlations between the squat and the first meters of the sprint and between SJ and the first meters of the sprint, these values are relevant since they complement each other to establish the force-velocity-power profile for each athlete.

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