INFLUENCE OF MAXIMAL ISOMETRIC STRENGTH ON 20-METER SPRINT TIME

ABSTRACT

Introduction: The 20-meter sprint 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.

Keywords: Muscle strength; Isometric contraction; Athletes.
INTRODUCTION

Back squat is a widely used exercise for the development of strength in sports, which increases force levels in the lower extremities. However, some studies emphasize that not all sports gestures are vertical; 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. In relation to the increase in performance in velocity athletic tests, different training methodologies have been used. However, and under the vector parameters of force application, most of these investigations have applied nonspecific exercises when compared to real sports movements. While there is a transference from the vertical forces developed through squats towards horizontal forces (sprint performance), 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. Currently, there are several tools for evaluating strength and speed. However, the assessment and training of strength in sprinters should be similar to the gestures developed in competitions. 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. 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. 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. 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 90° 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/BMI |
|--------------|-------------|---------------|--------------------------|---------------------|-------------|---------------|-------------|--------------|----------|
| 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     |

Descriptores: Fuerza muscular; Contracción Isométrica; Atletas.
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 90°, 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 with a FEMD (Dynasystem®, Symotech, Granada, Spain). The FEMD allows kinetic-toric control of the movement (0.10−1.5 m·s−1) and isometric assessment of muscle strength (5−3000 N) with a sampling frequency of 1.000 Hz (Dynasystem, Model Research, Granada, Spain). 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 90°, hands on hips and no countermovement. 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 90°, 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 90°, 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).
Newton (N).

**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 90°) |
|--------------|--------------------------------------------|----------------------------------------------------------|----------------------------------------------------------|-------------------------------------------|
|              | absolute (N) | relative (N) | absolute (N) | relative (N) | absolute (N) | mean | peak | mean | peak | mean | peak | mean | peak | mean | peak | mean | peak | mean | peak | mean |
| a            | 734.0        | 547.5        | 9.607       | 7.166       | 366.0        | 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 | 9.152 | 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 | 8.519 | 783.0 | 747.5 | 9.182 | 9.367 |
| mean         | 944.8        | 846.4        | 12.365      | 11.059      | 841.7        | 753.9 | 11.021 | 9.877 | 735.4 | 652.6 | 9.637 | 8.519 | 587.5 | 541.1 | 7.657 | 7.106 |
| SD           | 204.1        | 218.5        | 2.765       | 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  |

**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     | r          | -0.228      | -0.105      | -0.051       | 0.131        |
| Absolute peak       | r          | -0.337      | -0.224      | -0.106       | 0.046        |
| Isometric squat     | r          | -0.085      | -0.019      | 0.009        | 0.167        |
| Average peak        | r          | -0.214      | -0.151      | -0.056       | 0.077        |
| Isometric squat     | r          | -0.653      | -0.486      | -0.215       | -0.036       |
| Absolute peak       | r          | -0.659      | -0.438      | -0.166       | 0.003        |
| Isometric squat     | r          | -0.496      | -0.396      | -0.153       | 0.005        |
| Relative peak       | r          | -0.531      | -0.372      | -0.125       | 0.031        |
| Starting blocks     | r          | -0.228      | -0.105      | -0.051       | 0.131        |
| Absolute peak       | r          | -0.703      | -0.481      | -0.461       | -0.205       |
| Isometric squat     | r          | -0.270      | -0.418      | -0.613       | -0.538       |
| Relative peak       | r          | -0.465      | -0.325      | -0.367       | -0.146       |
| Starting blocks     | r          | -0.842      | -0.416      | -0.159       | 0.021        |
| Absolute peak       | r          | -0.826      | -0.355      | -0.079       | 0.025        |
| Isometric squat     | r          | -0.768      | -0.376      | -0.125       | 0.01         |
| Relative peak       | 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.13 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 exerted 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 sprints and blocks 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.17 Therefore, a key element to increase sprint performance is determining the specific vector parameters for each sport reality.16

There are studies that have connected a higher jumping height with the force levels of the lower extremities.13 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); these 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
5-m sprint (ms)

\[ r = -0.748; p = \text{ns} \]

(both knees at 90º)

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

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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