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A Specific Test of Starting Blocks: Intrasession and Intersession Reliability of Isometric Strength Using a Functional Electromechanical Dynamometer

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Abstract: Aims: To determine the intrasession and intersession reliability of the isometric force at three different starting block positions, to compare the intrasession and intersession reliability of the peak and average isometric force of three different starting block positions, and to compare the intrasession and intersession reliability of three different starting block positions. Methods: Eighteen male college students participated in this study. A repeated measures design was used to evaluate the intrasession and intersession reliability of isometric force in three different starting block positions. Results: Very high and extremely high reliability of the average and peak isometric force of the three positions of the starting blocks were obtained, with ICC ranging from 0.63 to 0.91 and a CV close to 10%. Peak force was able to determine the outcomes of the bilateral position with higher reliability than the mean force, and the dominant was the most reliable position for assessing the starting blocks. Conclusion: The functional electromechanical dynamometer can be used with a high level of reliability to assess the force exerted in the starting blocks.

Keywords: athletic performance; reproducibility of results; athletes; muscle strength; resistance training

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1. Introduction

Although sprint performance is largely dependent on genetic traits, key underlying elements such as power, technique, and specific endurance are trainable [1]. The sprint can be divided into three main phases: the block starts with the acceleration phase, which is sometimes subdivided into the initial acceleration and main acceleration phase (or pick-up), the maximum velocity phase, and the deceleration phase [2]. In this regard, a good start is characterized by an extraordinary force exerted in the horizontal direction, which is the main element of success in the sprint [3].

Thus, the starting blocks in velocity races can be critical to the outcome of a sprint. Starting from blocks is crucial in this type of event. It significantly affects the overall time in the 100 m sprint. Therefore, improving block performance can directly enhance sprint results. In the "Ready" position, an anthropometrically determined block adjustment that facilitates hip extension and contribution from the posterior leg should be encouraged. During cue take-off, rapid extension of both hips seems important for greater horizontal thrust and force production in that plane. After take-off, short flight times and higher propulsive forces [4] with short contact time [5] improve exit performance.

Furthermore, the starting block can be considered a sport-specific effort gesture [6], and its performance is determined by both maximizing horizontal power output capabilities and optimizing the mechanical profile in the application of force and velocity in the propulsion for sprinting [7]. Therefore, monitoring and assessing the force applied under specific conditions is essential [8]. This helps identify the athlete's strengths and weaknesses. Consequently, it allows for better performance prediction in competitions and enables personalized training programs to enhance sporting performance. However, numerous studies in the scientific literature have focused on analyzing measurement devices to predict strength performance in sprinters. These studies typically employ non-specific movements such as countermovement jumps [9,10] or squat strength assessments [11]. Moreover, a systematic review by Seitz et al. [12] demonstrated the transferability of squat strength to sprint performance.

Currently, few studies in the scientific literature assess the kinetic parameters of performance during the application of force in a specific cueing gesture. This is because no technology currently exists to assess this particular gesture [13]. The functional electromechanical dynamometer (FEMD) is an innovative tool that addresses this gap. It allows us to quantify, control, and manipulate the training load or manifestations of strength. This can be done directly and immediately, both in average and peak forces, using its different assessment modes [14]. Several authors have contributed to their studies on the reliability of this device by reproducing different sporting gestures [15,16]. In addition, a previous study determined that the maximum isometric force (MIF) exerted on the starting blocks using FEMD had a very high correlation with performance in the first 5 m of the sprint [13]. Considering that the starting blocks are a sporting gesture with a high horizontal component, performing the most functional assessment of strength possible is necessary. The assessment with FEMD makes it possible to specifically assess the gesture because of the different possibilities it offers for the assessment and development of the strength of a specific movement or sporting gesture, such as the starting blocks [13].

This study addresses a critical gap in the literature regarding the assessment of force application in sport-specific movements, such as the starting block phase in sprinting. Although the force and technique during the start are pivotal for sprint performance, existing technologies have been limited in their ability to accurately and specifically assess this action. By utilizing a FEMD, our study aims to provide reliable data on isometric force across different starting block positions. Ultimately, these advancements may lead to improvements in sprint times and performance assessments. Therefore, this study aimed to determine the intrasession and intersession reliability of the isometric force of three different starting block positions, using a FEMD to compare the intrasession and intersession reliability of the peak and average isometric force of three different starting block positions and to compare the intrasession and intersession reliability of three different positions of the starting blocks. We hypothesized that (i) the isometric strength of the three different starting block positions has high intrasession and intersession reliability, (ii) the average force is more reliable than the peak force, and (iii) the dominant position is the most reliable.

2. Materials and Methods

2.1. Experimental Design

A repeated measures design was used to evaluate the intrasession and intersession reliability of the isometric force in three different starting block positions. In order to reduce the standard error, participants initially participated in a familiarization session with three days of separation.

2.2. Participants

Eighteen male college students (age = 21.7 ± 2.1 years; weight = 70.8 ± 8.1 kg; height = 1.77 ± 0.06 m; body mass index = 22.7 ± 2.8 kg/m^2) with 7.40 ± 1.77 years of experience in sprinting and block start participated in this study. Regarding the inclusion criteria, (i) university students in physical activity and sports sciences, (ii) with a minimum of one year of experience in sprinting, (iii) who have practiced block start techniques,

(iv) with at least one year of prior experience in block starts; and (v) who have identified the leg positioned in the front block, which we classify as the dominant leg, were included. Participants were excluded from the study if they had any musculoskeletal injury that prevented them from performing the assessment. All participants were informed of the nature, aims, and risks associated with the experimental procedure before giving written consent to participate. The study protocol was approved by the Institutional Review Board of the University of Granada (n°1377/CEIH/2023) and was conducted in accordance with the Declaration of Helsinki.

2.3. Procedures

All test sessions were conducted in the Strength and Conditioning Laboratory and the running track of the Faculty of Sports Science of the University of Granada (Granada, Spain). Participants came to the assessment on five different days (72 h apart). In the first session, information was collected from each subject (personal data, sporting experience, and anthropometric data), and familiarization with the warm-up to be performed in the following sessions was conducted. Body mass (kg) was assessed using an electronic scale (SECA 861, Hamburg, Germany) with an accuracy of 100 g, and height (cm) was assessed using a precision stadiometer (SECA 225, Hamburg, Germany) to the nearest 0.1 cm. BMI was calculated as body mass (kg)/height (m^2). In addition, leg length was measured. All anthropometric measurements were conducted by AR-P.

The warm-up included a general part with a foam roller, ballistic leg throws, and activation with elastic bands, as well as a specific part with squats, steps, countermovement jumps, and starting blocks acceleration. In the second, third, fourth, and fifth sessions, once the warm-up was completed and with a rest of 3 min, the isometric strength tests of the three different starting block positions were measured with the FEMD. After a complete rest (5 to 10 min), the same tests were repeated. All assessments were performed by an expert athlete coach (FM-P) and an assessor experienced with the measuring device at the same time of day (± 1 h) for each participant and under similar environmental conditions (∼21 °C and ∼60% humidity). The order and sequence of tests (bilateral, dominant, and non-dominant) were randomized to prevent any effects on learning and fatigue using a computerized system (www.random.org, accessed on 1 October 2023).

2.3.1. Position Individualization

The front block was positioned at a standardized distance of 1.90 m from the MYO device for all athletes (D1). This initial setup was further customized based on individual anthropometric measurements to ensure optimal positioning for each athlete, as recommended by Cavedon et al. [17]. Specifically, the length of each participant's leg was estimated using the model proposed by Winter [18], which calculates leg length (LL) as 53% of the participant's height ($LL = 0.53 \cdot h$), where h represents the participant's height. Subsequently, the distance from the front block to the participant's start position was set at 60% of their calculated leg length (D2). Additionally, the distance from the front block to the starting line was adjusted to 45% of the leg length (D3), as illustrated in Figure 1. This individualized setup was crucial to ensure that the force exerted during the test accurately reflected each athlete's biomechanics, thereby enhancing the reliability of the measurements captured.

2.3.2. Positions of the Starting Blocks

After the warm-up, the different positions to be performed in each of the tests were checked and established, as well as the optimal distance between feet for each of them. Thus, firstly, with the help of a cable/simulator, the optimal distance of the heels was checked and established according to the anthropometry, the main instructions being that the athlete in the "ready" position should be comfortable, stable and that this position, after a start signal, should allow him/her to press in isometric contraction against the heels with the sensation of the horizontal projection of the hip for at least 6" in each of the positions: bilateral, dominant, and non-dominant.

Figure 1. Standardization of the initial position. D1 = distance to the starting block:1.90 (m); D2 = 60% lower body length; D3 = 45% lower body length.

2.3.3. Isometric Strength Tests with FEMD in the Initial Position of the Starting Blocks

Isometric force was evaluated using FEMD (Myoquality M1, Myoquality Solutions, Granada, Spain) in three different "ready" starting block positions. The mechanical characteristics of this device include an accuracy of three millimeters for displacement, a variation of 100 g when determining a load, and a sampling frequency of 1000 Hz. The different positions involved both feet at the same height (bilateral), the dominant leg on the front block (dominant), and the non-dominant leg on the front block (non-dominant). The dominant leg was determined by the leg positioned in the front block during a block start, and the non-dominant leg was determined by the leg positioned in the rear block, as established by each athlete based on their prior experience. Subjects were positioned on the starting blocks in an elevated stance, feet firmly on the blocks and toes touching the tartan. A slight knee flexion was maintained to allow for balance and positioning of the hands on the starting line in the 'ready' position. This posture also facilitated a slight horizontal preload against the blocks. Prior to recording, participants were instructed to react to the verbal cue 'ready' followed by the command 'now', upon which they were to apply maximal horizontal force against the blocks by dynamically pulling and pushing forward for a duration of 6 s. It was crucial that participants maintained hand contact with the tartan throughout the exertion period. The FEMD was set to isometric mode and commenced data capture immediately after the 'now' command. During the effort, verbal encouragements were provided to help subjects sustain maximum force output. The FEMD cable was secured to the participant using a robust double-securing system. This involved a weightlifting belt with an integrated ring at the waist, padded at the sacrum to avoid discomfort. The end of the FEMD cable was then attached above the sacrum's base. To minimize horizontal displacement during the test, the belt was further secured by a harness system tailored to the athlete's upper body, which was adjusted based on their anthropometric data to ensure optimal alignment and safety (Figure 2).

Figure 2. Pre-test positions.

2.4. Statistical Analyses

Prior to recruiting participants for our study, to ensure adequate statistical power for our reliability study with 8 repeated measurements, we calculated the required sample size using G*Power 3.1. We conducted an a priori power analysis for repeated measures ANOVA within factors. The analysis parameters included a moderate effect size (f = 0.25), a significance level (α) of 0.05, a desired power (1-β) of 0.8, a single group, 8 measurements, an assumed correlation of 0.5 among repeated measures, and a nonsphericity correction (ε) of 1.0. Based on these settings, the analysis determined that a total sample size of 16 subjects would achieve an actual power of 0.819. This sample size is sufficient to detect a moderate effect while minimizing the risk of Type II errors, thereby ensuring the reliability of the results in our repeated measures design.

Descriptive data are presented as mean ± standard deviation (SD). The normality of the data was assessed using the Shapiro–Wilk test. The relative reliability of the three different starting block positions was investigated using a *t*-test and intraclass correlation coefficient (ICC). Following Hopkins et al. [19], we classified the magnitude of the ICC values through a qualitative scale: values close to 0.1 are considered low reliability; 0.3, moderate; 0.5, high; 0.7, very high; and those close to 0.9, extremely high [19]. We also examined the differences between the test and retest using different error measures. The sum of squared errors (SSE), the mean sum of squared errors (MSE), the root mean sum of squared errors (RMSE), and the percentage error was calculated.

The following methods were used to study absolute reliability: standard error of measurement (SEM) as a percentage of the mean value of the measurements, standard error of estimate (SEE), the coefficient of variation (CV), and Bland–Altman plots [20,21], with a value of SEM ≤ 15% and CV ≤ 10% considered acceptable [22]. The heteroscedasticity of errors was also identified in the Bland–Altman plots and defined as a coefficient of determination (r2) > 0.1. To estimate the smallest change in score that indicates a "real change" in 90% of the participants, the minimal detectable change (MDC_{90}) was calculated.

Finally, Cohen's d was computed to quantify the magnitude of the difference between the test and retest. The scale used for the magnitude of the ES was specific to training research: negligible (<0.2), small (0.2–0.5), medium (0.5–0.8), and large (>0.8) [23].

Separate analyses were performed for each position and strength manifestation. To interpret the observed magnitude of differences in the coefficients of variation of the two-strength manifestation, the mean of the CV of all conditions was made, and a default for the smallest important ratio of 1.15 was used [24].

All analyses were performed using the Statistical Package for Social Sciences (IBM SPSS Statistics for Windows, version 26.0; Armonk, NY, USA), and the level of significance was set at $p < 0.05$.

3. Results

Table 1 shows the descriptive characteristics of the sample, with 33% being left-dominant. Intrasession test–retest reliability of the average and peak isometric strength of the three positions of the starting blocks is shown in Table 2. A non-significance difference was found between the test and retest of average and peak force, except for the first session in the dominant leg position ($p = 0.03$). Very high and extremely high reliability of the average and peak isometric force of the three positions of the starting blocks were obtained with the ICC ranging from 0.63 to 0.91 and a CV close to 10%.

Table 1. Descriptive characteristics of the sample.

Participants.	Age	Dominant Foot	Experience	Weight	Height	BMI
	(year)		(years)	(kg)	(m)	(kg/m^2)
S1	25.0	Left	9	75.0	1.69	26.3
S2	24.0	Left	7	74.8	1.85	21.8
S3	21.0	Right	6	69.2	1.68	24.7
S4	20.0	Right	7	60.2	1.74	20.0
S5	20.0	Right	8	68.9	1.74	22.9
S6	22.0	Right	9	72.8	1.77	23.4
S7	25.0	Left	7	87.0	1.75	28.4
S8	24.0	Right	10	84.5	1.86	24.4
S9	21.0	Left	9	57.4	1.71	19.6
S10	27.0	Right	12	83.0	1.71	28.4
S11	21.0	Right	6	77.8	1.74	25.7
S12	21.0	Right	6	72.5	1.74	23.9
S13	20.0	Right	8	61.2	1.84	18.1
S14	20.0	Right	4	62.6	1.76	20.2
S15	20.0	Right	6	70.7	1.83	21.2
S16	21.0	Left	8	69.2	1.81	21.1
S17	20.0	Left	7	64.5	1.75	21.1
S18	20.0	Right	8	72.9	1.85	21.3
mean	21.7		7.40	70.88	1.77	22.74
SD	2.1		1.77	8.12	0.06	2.88

Note: kg = kilograms; m = meters; BMI = body mass index; SD = standard deviation.

On the other hand, the intersession test–retest reliability of the average and peak isometric strength of the three positions of the starting blocks is shown in Table 3. A non-significant difference was found between the test and retest of average and peak force ($p > 0.05$). Very high and extremely high reliability of the average and peak isometric strength of the three positions of the starting blocks were obtained between the third and fourth sessions, with the ICC ranging between 0.84 and 0.92 and a CV close to 10%.

Figure 3 shows the Bland–Altman plots of the reliability between the third and fourth session of the average and peak isometric force of the three positions of the blocks. The random error was close to eight kilograms and narrow LoA. Heteroscedasticity of errors was observed ($r^2 > 0.10$) between test and retest in bilateral peak force ($r^2 = 0.142$) and non-dominant peak force ($r^2 = 0.101$).

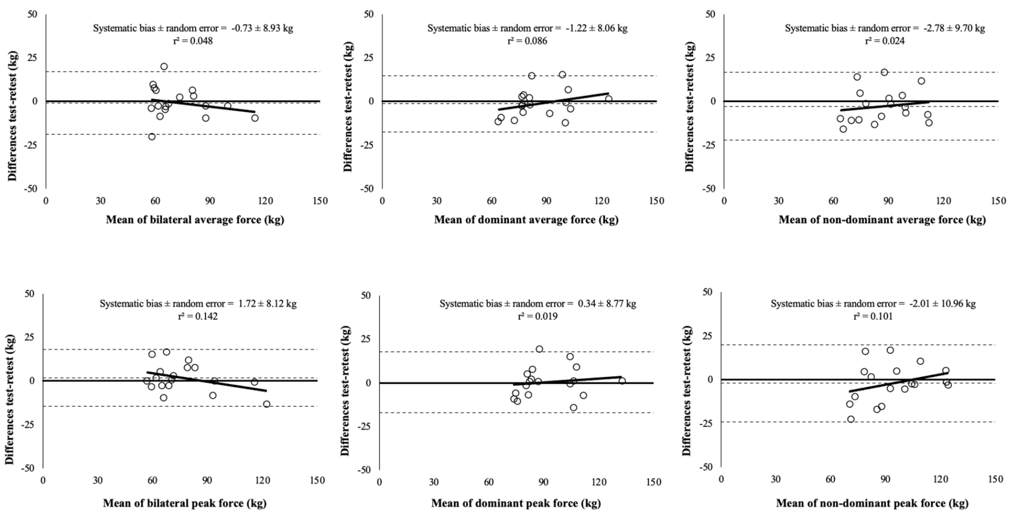

Figure 3. Bland-Altman plots.

Table 2. Intrasession test–retest reliability of isometric strength of three different starting block positions.

	Test (kg)	Retest (kg)	*p*-Value	Cohen's d	ICC (95% CI)	SSE	MSE	RMSE	% Error	% CV	SEM	MDC_{90}	SEE
Peak Force													
Bilateral Position													
T1–T2	69.2 ± 16.3	69.2 ± 12.6	0.97	0.00	0.87 (0.68–0.95)	1063.37	12.97	3.60	6.52	8.08	5.59	0.00	5.97
T3–T4	73.5 ± 19.7	73.5 ± 17.7	1.00	0.00	0.84 (0.62–0.94)	2116.14	25.81	5.08	6.21	10.73	7.89	0.00	9.96
T5–T6	74.7 ± 16.2	80.2 ± 22.3	0.18	0.28	0.68 (0.32–0.87)	5043.10	61.50	7.84	13.03	14.88	11.52	−0.17	16.27
T7–T8	73.4 ± 19.4	78.0 ± 23.7	0.14	0.21	0.85 (0.64–0.94)	3055.42	37.26	6.10	8.60	11.71	8.87	−0.15	12.52
Dominant Leg Position													
T1–T2	82.9 ± 15.7	88.5 ± 15.8	0.07	0.35	0.72 (0.39–0.88)	3121.44	38.07	6.17	11.20	10.13	8.68	−0.16	11.35
T3–T4	90.2 ± 14.8	85.4 ± 21.5	0.18	−0.26	0.72 (0.39–0.89)	3925.53	47.87	6.91	14.41	11.58	10.17	0.12	14.32
T5–T6	93.1 ± 20.1	92.2 ± 16.2	0.69	−0.05	0.86 (0.67–0.95)	1749.79	21.33	4.62	6.44	7.71	7.14	0.02	8.07
T7–T8	93.5 ± 15.5	91.1 ± 18.3	0.24	−0.15	0.88 (0.71–0.95)	1420.22	17.31	4.16	8.72	6.73	6.21	0.06	8.75
Non-Dominant Leg Position													
T1–T2	81.9 ± 18.5	84.9 ± 19.7	0.41	0.16	0.70 (0.35–0.87)	4261.21	51.97	7.21	10.55	13.15	10.97	−0.09	14.59
T3–T4	84.8 ± 26.5	91.6 ± 19.0	0.18	0.29	0.63 (0.25–0.84)	7921.48	96.60	9.83	8.47	16.38	14.45	−0.19	14.61
T5–T6	93.9 ± 20.7	92.7 ± 21.6	0.69	−0.06	0.84 (0.63–0.94	2662.73	32.47	5.69	8.01	9.44	8.81	0.03	12.13
T7–T8	96.4 ± 18.7	94.2 ± 17.4	0.49	−0.12	0.77 (0.48–0.91)	2896.24	35.32	5.94	8.40	9.55	9.10	0.05	11.55
Average Force													
Bilateral Position													
T1–T2	63.6 ± 14.7	64.2 ± 10.9	0.72	0.05	0.85 (0.64–0.94)	956.64	11.67	3.42	7.08	8.62	5.28	−0.02	5.37
T3–T4	68.5 ± 16.7	69.6 ± 16.6	0.60	0.07	0.87 (0.68–0.95)	1429.84	17.44	4.18	6.44	9.31	6.43	−0.04	8.73
T5–T6	69.4 ± 15.7	75.0 ± 18.2	0.08	0.33	0.75 (0.45–0.90)	3236.79	39.47	6.28	10.65	12.33	8.87	−0.19	12.33
T7–T8	70.3 ± 16.6	75.4 ± 20.7	0.10	0.27	0.80 (0.54–0.92)	3133.88	38.22	6.18	9.76	12.14	8.85	−0.17	12.52
Dominant Leg Position													
T1–T2	74.8 ±13.9	82.1 ± 16.2	0.03	0.48	0.67 (0.31–0.86)	3718.24	45.34	6.73	14.45	11.50	9.02	−0.23	12.31
T3–T4	82.1 ± 12.6	81.7 ± 17.2	0.90	−0.02	0.74 (0.43–0.90)	2175.65	26.52	5.15	12.18	9.76	8.00	0.01	11.30
T5–T6	85.7 ± 17.6	85.4 ± 18.0	0.88	−0.02	0.91 (0.78–0.97)	1079.41	13.16	3.63	5.52	6.58	5.63	0.01	7.83
T7–T8	88.2 ± 14.8	85.3 ± 16.0	0.09	−0.19	0.91 (0.78–0.97)	956.19	11.66	3.41	6.63	5.60	4.86	0.08	6.86

Table 2. *Cont.*

	Test (kg)	Retest (kg)	*p*-Value	Cohen's d	ICC (95% CI)	SSE	MSE	RMSE	% Error	% CV	SEM	MDC_{90}	SEE
Non-Dominant Leg Position													
T1–T2	74.4 ± 14.3	79.4 ± 18.5	0.13	0.30	0.70 (0.36–0.88)	3458.10	42.17	6.49	12.45	12.24	9.42	−0.16	13.25
T3–T4	80.7 ± 16.1	83.6 ± 15.9	0.33	0.18	0.72 (0.40–0.89)	2787.85	34.00	5.83	9.25	10.71	8.80	−0.09	11.39
T5–T6	86.0 ± 17.9	85.1 ± 17.8	0.74	−0.05	0.81 (0.57–0.93)	2262.00	27.59	5.25	8.29	9.51	8.13	0.02	10.87
T7–T8	90.2 ± 17.3	86.4 ± 15.2	0.14	−0.23	0.81 (0.57–0.93)	2105.58	25.68	5.07	7.76	8.36	7.38	0.10	9.10

Note: The data are presented as mean ± SD. SD = standard deviation; ICC = intraclass correlation coefficient; CI = confident interval; SSE = sum of squared errors; MSE = mean sum of squared errors; RMSE = root mean sum of squared errors; %Error = percentage error; %SEM = standard error of measurement; MDC_{90} = minimal detectable change in 90% of participants; %CV = percentage coefficient of variation; SEE = standard error of estimate.

Table 3. Intersession test–retest reliability of isometric strength of three different starting block positions.

	Test (kg)	Retest (kg)	*p*-Value	Cohen's d	ICC (95% CI)	SSE	MSE	RMSE	% Error	% CV	SEM	MDC_{90}	SEE
Peak Force													
Bilateral Position													
S1–S2	69.2 ± 14.0	73.6 ± 17.9	0.37	0.27	0.24 (−0.24–0.63)	7092.70	86.50	9.30	18.16	19.74	14.09	−0.15	17.38
S3–S4	77.5 ± 17.8	75.7 ± 20.8	0.38	−0.09	0.92 (0.80–0.97)	1173.90	14.32	3.78	6.40	7.49	5.74	0.05	8.00
Dominant Leg Position													
S1–S2	85.7 ± 14.5	87.8 ± 17.0	0.58	0.13	0.51 (0.07–0.78)	4466.42	54.47	7.38	15.94	13.09	11.36	−0.06	14.84
S3–S4	92.6 ± 17.5	92.3 ± 16.4	0.87	−0.02	0.88 (0.71–0.95)	1309.35	15.97	4.00	6.22	6.71	6.20	0.01	8.12
Non-Dominant Leg Position													
S1–S2	83.4 ± 17.5	88.2 ± 20.7	0.33	0.25	0.47 (0.01–0.76)	7347.40	89.60	9.46	13.37	16.64	14.28	−0.13	18.44
S3–S4	93.3 ± 20.2	95.3 ± 16.9	0.45	0.11	0.84 (0.63–0.94)	2116.00	25.80	5.08	7.72	8.22	7.75	−0.05	9.15

Table 3. *Cont.*

	Test (kg)	Retest (kg)	*p*-Value	Cohen's d	ICC (95% CI)	SSE	MSE	RMSE	% Error	% CV	SEM	MDC_{90}	SEE
Average Force													
Bilateral Position													
S1–S2	63.9 ± 12.4	69.1 ± 16.0	0.22	0.36	0.31 (−0.17–0.67)	5429.87	66.22	8.13	19.06	18.15	12.07	−0.19	15.28
S3–S4	72.2 ± 15.8	72.9 ± 17.7	0.73	0.04	0.87 (0.69–0.95)	1363.95	16.63	4.07	6.63	8.70	6.31	−0.02	8.91
Dominant Leg Position													
S1–S2	78.4 ± 13.7	81.9 ± 14.0	0.24	0.25	0.64 (0.26–0.85)	2745.27	33.48	5.87	13.77	10.75	8.62	−0.10	11.07
S3–S4	85.5 ± 17.3	86.7 ± 15.1	0.53	0.07	0.89 (0.73–0.96)	1130.45	13.79	3.71	5.54	6.61	5.70	−0.03	6.99
Non-Dominant Leg Position													
S1–S2	76.9 ± 15.1	82.1 ± 14.8	0.14	0.35	0.58 (0.17–0.82)	3898.28	47.54	6.89	11.67	12.59	10.01	−0.16	12.33
S3–S4	85.5 ± 16.9	88.3 ± 15.5	0.24	0.17	0.84 (0.62–0.94)	1738.65	21.20	4.60	8.18	7.89	6.86	−0.08	8.76

Note: The data are presented as mean ± SD. SD = standard deviation; ICC = intraclass correlation coefficient; CI = confident interval; SSE = sum of squared errors; MSE = mean sum of squared errors; RMSE = root mean sum of squared errors; %Error = percentage error; %SEM = standard error of measurement; MDC_{90} = minimal detectable change in 90% of participants; %CV = percentage coefficient of variation; SEE =standard error of estimate.

The values from session three and session four (intersession reliability) were used to compare the CVs through the CVratio, and it revealed that the peak force was able to determine the outcomes of the bilateral position with higher reliability than the mean force. There are no significant differences in reliability between the peak force and the average force for the dominant position and the non-dominant position (Figure 4A). Furthermore, the dominant is the most reliable position for assessing the starting blocks with both the peak force and the mean force variable (Figure 4B).

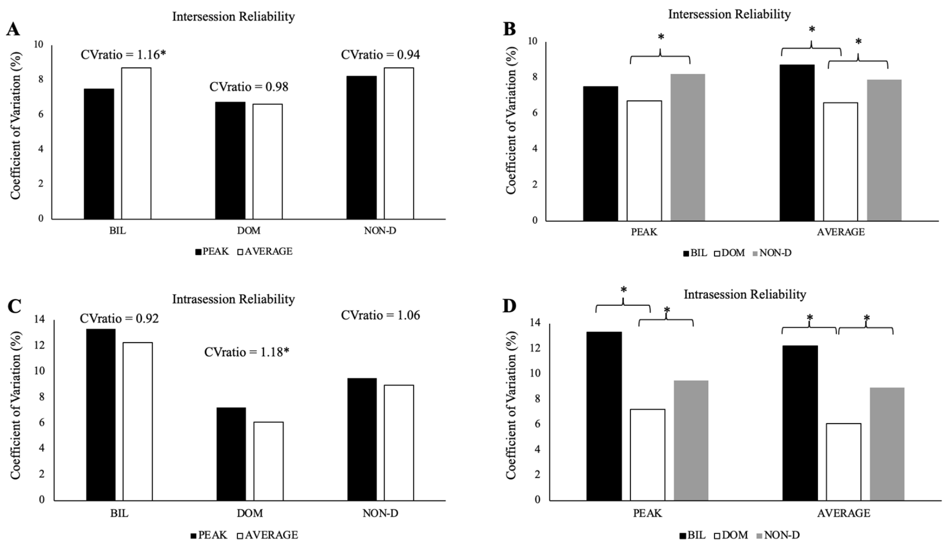

Figure 4. Comparison of the inter- and intra-session reliability of peak and average force results between the three different starting block positions (left panel **A**,**C**) and comparison of the inter- and intra-session reliability of the results of the three different starting block positions between peak and average force (right panel **B**,**D**). * Meaningful differences in reliability were identified by a CVratio higher than 1.15.

The mean values from tests five and six and tests seven and eight (intrasession reliability) were used to compare the CVs through the CVratio, and only the dominant position presented significant differences in reliability (CVratio > 1.15), being the average force with more reliability (Figure 4C). When the three positions were compared, there were significant differences between bilateral and dominant and non-dominant in peak and average force; however, no differences were found between bilateral and non-dominant positions in peak and average force (Figure 4D).

4. Discussion

The aims of the study were to determine the intrasession and intersession reliability of isometric force by using a FEMD of three different starting block positions. The main finding of our study shows that intrasession and intersession reliability was moderate to extremely high in terms of the average and peak isometric strength of the three positions of the starting blocks. Therefore, the use of devices that measure the horizontal force exerted is transcendental, given the correlation between performance and this type of device, even superior to squat performance, which has been extensively studied [13].

Firstly, the first hypothesis indicated that intrasession and intersession reliability would be high with the device used. In this sense, in the bilateral position and with the non-dominant leg, we observed that the intrasession peak force measurements did not obtain high reliability, where the results in the first measurements T1–T2 and T3–T4 (first and second session) were much more accurate than in the last ones. This could be justified given that authors such as Doma et al. [21] found a high variability when two measurements are taken in one session (T1–T2), recommending a third measurement to reduce this error due to the lower variability between T2 and T3.

However, it should be noted that in the position with the dominant leg, there was a more favorable trend towards familiarization comparing T1–T2 and T7–T8 for both peak strength ($p = 0.07$ vs. $p = 0.24$) and mean strength ($p = 0.03$ vs. $p = 0.09$). This finding is likely attributable to the athlete's condition, particularly given the importance of familiarization with specific movements to ensure adequate reliability between measurements. Most studies perform analyses that consider the most ergonomic position of the sprinters, which remains consistent across measurements [25,26]. Additionally, in the cueing gesture, the force exerted in the horizontal direction is a critical factor requiring maximum ergonomic efficiency [3]. In the case of the mean force for the other two positions, no clear trend is found, since both the *p*-value and the ICC did not change positively or negatively.

In turn, describing the average strength in the non-dominant leg, it occurred similarly to the dominant leg, finding differences from T1 to T2 and T7 to T8 (sessions one and four) with an ICC that went from 0.67 to 0.91 (position dominant) and from 0.70 to 0.81 (non-dominant position). This finding can be justified due to the nature of FEMD, where muscle involvement is evaluated in a much more specific position and environment than with other devices, for example, using linear velocity transducers [27]. It can be modified, especially when looking for a maximum peak strength. Finally, it should be noted that the ICC values were higher than 0.80 for the last of the sessions in the three positions for the average force and for the peak force (except in this case, for the non-dominant leg), which indicates the importance of the familiarization with the instrument to ensure adequate reliability. Discussing the results with the dominant leg as most studies are carried out, it should be noted that this reliability was high as for other authors with measurement devices in the starting blocks such as that of García-Ramos et al. [28] with a CV < 15%, values even higher than our data with the dominant leg (CV = 5.6–11.58%), or the study by Wibowo et al. [3] also finding a high relationship between stud output power measured with a stud measurement device and sprint performance.

Secondly, regarding intersession reliability, it is highlighted that the results showed high reliability between sessions three and four. In this case, less variability is observed between sessions three and four for the three positions, both in the peak force and in the average force. Specifically, in the dominant force, a CV of 13.09% and 10.75% was found in the peak and average force, respectively (sessions one and two) and 6.71% and 6.61% (sessions three and four). Thus, this is in line with other research, such as that of Doma et al. [21] where they reached this conclusion on the reliability of the sprint with a CV of 4.3 to 20.7% (between sessions one and two) and 3.2–10.1% (between sessions three and four), conclusions similar to those of Tofari et al. [29] or those of García-Ramos et al. [28] with three devices for measuring force in the blocks, highlighting that for these authors, the intrasession CV was lower than the intersession as in our research. At the same time, this result is not new, given that authors such as Hopker et al. [30] also saw this need; therefore, familiarization with at least two sessions and two trials per session was essential to achieve adequate reliability [28]. It is noteworthy that in our case, the intraclass correlation coefficient (ICC), which shows the degree of agreement between the different measurements, was very high, especially in the average force in the three positions, but they were only higher in both the peak force as in the average strength at 0.80, between the third and fourth session, this value was considered adequate [31].

Given this first hypothesis, we can also respond to the second hypothesis, not including whether there was a trend in favor of greater reliability in peak force or average force. However, when there was familiarization with the instrument (from the second session), except in the bilateral position, the average force had greater reliability than the peak force. It is noteworthy that in all cases, the reliability of the instrument for the dominant leg was very high, both intrasession and intersession, both in average force and in peak force. This responds to the third of the hypotheses of the present study since it is hypothesized that the dominant leg would be the most reliable position. The higher reliability observed in the dominant leg position can be attributed to greater neuromuscular efficiency and improved motor control because the dominant leg is typically more engaged in dynamic movements.

Additionally, the dominant leg, being more familiar with sport-specific actions, such as the starting block push-off, tends to have stronger musculature and better coordination, leading to reduced measurement variability. These biomechanical factors optimize the force transmission and contribute to a more consistent performance, thereby explaining the high reliability in this position. As it is the position with greater ergonomics and where there is greater familiarization in athletes, it is notable that this result exists, given that in unfavorable ergonomic conditions, when modifying the leg, performance and reliability can be reduced [32]. The dominant leg typically generates a greater and more consistent force during the push-off phase, which significantly contributes to the acceleration phase of a sprint. This reliability in force production ensures a more stable and efficient start, which is crucial for achieving optimal sprint times. It would be interesting to see if, with higher level sprinters, it could be considered that the differences were even greater with respect to the other two positions due to the lack of habit of the technical gesture, given that the front leg produces the greatest impulse, but learning the use of the starting blocks also has a great impact on performance, especially due to the pre-tension accumulated in the muscles [33]. Although the FEMD device can be used in any position, logic indicates that in the real racing position, it is the most appropriate effect, considering that the angles and other aspects are very dependent on the athlete and do not seem to influence performance at the start, but the position of the forward leg and the placement of the studs does.

Considering the results, it is worth highlighting that coaches and physical trainers can take into account the importance of the position and the use of the starting blocks in sprints and, above all, be able to use a FEMD to measure the performance of athletes and train with resistance.

The main limitation of the study is that the sample size of subjects was quite small, which means that if any of the participants performed a very different peak or average force between sessions or intrasession, it could substantially modify the results. On the other hand, the level of the athletes could have been very dispersed as specific selection criteria were not specified to ensure their sporting level, and being a device focused on such a specific technique (being a free gesture), the recruitment of the sample should be contemplated for a higher sporting level. In turn, the fatigue existing between the two measurements within the same session (second intrasession shot) or lack of familiarization (first shot) can also influence the results between the two measurements, together with the environment that was carried out in the laboratory and not on a real athletics track. It is therefore recommended to follow instructions such as those of Doma et al. [20] and carry out at least two familiarization sessions and two maximum measurements in each session prior to the analysis. However, the mechanical equipment required for this method may be limited in real-world applications; thus, several strategies can mitigate these challenges. Portable versions of FEMD are becoming increasingly available, allowing for field testing rather than being limited to laboratory settings. Despite these limitations, the proposed method offers distinct advantages over existing techniques, such as the ability to assess force production in sport-specific movements rather than relying on less specific tests such as countermovement jumps and squat strength assessments. This specificity can lead to more accurate assessments of an athlete's performance capabilities and better training interventions.

As future perspectives, it is suggested to include participants of different levels of performance in the starting blocks exit, in addition to including female athletes in order to generalize the results, given that authors such as Hopker et al. [30] found differences in sprint reliability between athletes of both sexes. Additionally, studying validity against other dynamometers. On the other hand, the use of the platform on an athletics track could improve the results by seeking a real context of application. Finally, it is recommended to carry out research to verify the relationship between sprint performance and lower body strength using this device, given the relationship between these two variables [13,34].

5. Conclusions

The FEMD device demonstrates high reliability for assessing force in starting block exits, applicable to both peak and average force measurements. However, a period of familiarization is necessary to obtain reliable results and, at the same time, to consider the position of the athlete, always looking for the use of the dominant leg forward. The absence of differences in peak and average force across conditions suggests the generalizability of these reliability values.

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