applied sciences

MDPI

*Article*

# Test–Retest Reliability of Concentric and Eccentric Muscle Strength in Knee Flexion–Extension Controlled by Functional Electromechanical Dynamometry in Female Soccer

**Oscar Andrades-Ramírez [1,2], David Ulloa-Díaz [3,*], Angela Rodríguez-Perea [4,5], Sergio Araya-Sierralta [6], Francisco Guede-Rojas [7], Gustavo Muñoz-Bustos [8] and Luis-Javier Chirosa-Ríos [1]**

1 Department of Physical Education and Sport, Faculty of Sport Sciences, University of Granada, 18011 Granada, Spain; oandrades@correo.ugr.es (O.A.-R.); lchirosa@ugr.es (L.-J.C.-R.)
2 Facultad de Salud y Ciencias Sociales, Escuela de Ciencias de la Actividad Física, Universidad de las Américas, Concepción 4030000, Chile
3 Department of Sports Sciences and Physical Conditioning, Universidad Católica de la Santísima Concepción, Concepción 4030000, Chile
4 Strength & Conditioning Laboratory, CTS-642 Research Group, Department of Physical Education and Sports, Faculty of Sport Sciences, University of Granada, 18011 Granada, Spain; arodriguezperea@ugr.es
5 Department of Physical and Sport Education, University of León, 24071 León, Spain
6 Facultad de Humanidades y Educación, Universidad de Atacama, Copiapó 1531772, Chile; sergio.araya@uda.cl
7 Exercise and Rehabilitation Sciences Institute, School of Physical Therapy, Faculty of Rehabilitation Sciences, Universidad Andres Bello, Santiago 7591538, Chile; francisco.guede@unab.cl
8 Facultad de Salud, Escuela de Nutrición y Dietética, Universidad Santo Tomas, Iquique 1100000, Chile; g.munoz.bustos@gmail.com
* Correspondence: dulloa@ucsc.cl; Tel.: +56-9-88133864

check for updates

**Citation:** Andrades-Ramírez, O.; Ulloa-Díaz, D.; Rodríguez-Perea, A.; Araya-Sierralta, S.; Guede-Rojas, F.; Muñoz-Bustos, G.; Chirosa-Ríos, L.-J. Test–Retest Reliability of Concentric and Eccentric Muscle Strength in Knee Flexion–Extension Controlled by Functional Electromechanical Dynamometry in Female Soccer. *Appl. Sci.* **2024**, *14*, 8744. https://doi.org/10.3390/app14198744

Academic Editor: Silvestro Roatta

Received: 22 August 2024
Revised: 15 September 2024
Accepted: 26 September 2024
Published: 27 September 2024



**Abstract:** In the field of sports performance, sports medicine, and physical rehabilitation, there is a great interest in the development of protocols and reliable techniques and instruments for the evaluation of strength produced by athletes. In the last ten years, women's football has increased its popularity and participation in numerous countries, which has contributed to players developing more professionally and requiring more specific muscle strength training to improve their performance. The aim of this study was to analyze the absolute and relative test–retest reliabilities of peak muscle strength in knee flexion (FLE) and extension (EXT) controlled using a functional electromechanical dynamometer (FEMD) in a group of seventeen professional female soccer players (age = 18.64 ± 0.62 years; weight = 54.72 ± 7.03 kg; height = 1.58 ± 0.04 m; BMI = 21.62 ± 2.70 kg/m$^2$). Peak muscle strength was measured with knee flexion (FLE) and extension (EXT) movements at a speed of 0.4 m·s$^{-1}$ unilaterally in a concentric phase (CON) and an eccentric phase (ECC). No significant mean differences were found in the test–retest analysis ($p > 0.05$; effect size < 0.14), and high reliability was reported for peak muscle strength assessments in both the CON (ICC) = 0.90–0.95) and the ECC (ICC = 0.85–0.97). Furthermore, stable repeatability was presented for extension in the CON (CV = 7.39–9.91%) and ECC (CV = 8.65–13.64). The main findings of this study show that peak muscle strength in knee flexion and extension in CON and ECC is a measure with acceptable absolute reliability and extremely high relative reliability using the FEMD in professional female soccer players.

**Keywords:** muscle strength; dynamometer; reliability; female soccer

## 1. Introduction

In the field of sports performance, medicine, and physical rehabilitation, there is a great interest in the creation of protocols and reliable techniques and instruments for the evaluation of the multiple manifestations of muscle strength produced by athletes [1,2].

According to several studies [3–6], well-developed muscular strength and power reduce the probability of injury during competitive play and influence the performance of a soccer player. Because this physical capacity facilitates fast movements such as sprinting, jumping, and changes in direction, high-intensity actions are fundamental during competition in both men's and women's soccer [7–9].

Over the last ten years, women's soccer has increased in popularity and participation in numerous countries, which has contributed to players developing more professionally and requiring more specific muscle strength training to improve their performance [10,11]. When organizing personalized training programs, a deeper understanding of the changes in players' physical performance is necessary due to the increasing performance level and competitive expectations of sports teams [12]. Therefore, to analyze an athlete's degree of physical fitness and, more importantly, muscle force production, they must be assessed using accurate equipment and reliable measurements [13].

There are currently devices on the international market that evaluate muscle strength with concentric or eccentric resistance, allowing for the free and multi-joint movement of the entire body using a cable or rod without proximal stabilization. One such device is the functional electromechanical dynamometer (FEMD), which incorporates a reel around which a cable is wound to the device [14]. In comparison to the gold standard or isokinetic device, the FEMD is less expensive and easier to use. It can perform in two modes, (a) dynamic with movement (tonic, kinetic, elastic, inertial, and conical) and (b) static without movement (isometric and vibratory), allowing for training and evaluation through a stable and variable resistance/speed [15,16].

Prior studies have demonstrated the validity [17] and reliability of FEMD in a variety of experimental settings, such as in the study by de Andrades-Ramírez et al. [18], which presented an acceptable absolute reliability for all strength assessments (CV < 10%) and an extremely high relative reliability (ICC = 0.92–0.99) in assessments of peak isometric and isometric/vibratory muscle strength in young university students. In the study by Baena-Raya et al. [19], the FEMD was found to have high absolute (CV = 2.22–2.51%) and relative (ICC = 0.94–0.95) reliability for peak muscle strength in twenty-seven male collegiate athletes for an isometric mid-thigh pull-up exercise. In the study by Jerez-Mayorga et al. [20], relative reliability classified as "high" (ICC = 0.95–0.98) and absolute reliability classified as "stable" (CV < 10%) were observed for the muscle strength assessment protocols used and for mean and peak muscle strength in the concentric phase of five sit-to-stand measurements using three incremental loads controlled by an FEMD in sixteen healthy young adult subjects. Martinez-Garcia et al.'s study [21] reported that the absolute reliability was "acceptable" (CV = 5.12–8.27%) and relative reliability was "extremely high" (ICC = 0.81–0.98) of the FEMD for mean muscle strength in a strength test of the shoulder internal and external rotators in standing position in the concentric and eccentric phases in thirty-two young university students.

In a previous study, Sánchez-Sánchez et al. [22] analyzed the reliability of a FEMD on eccentric swing exercise measurements of a hamstring strength movement in male soccer players, presenting a "high" absolute reliability (CV = 2.80%) and "extremely high" relative reliability (ICC = 0.94) in mean muscle strength for a velocity of 0.4 $m \cdot s^{-1}$. In addition, high absolute reliability (CV = 4.66%) and "extremely high" reliability relative (ICC = 0.91) were obtained for peak muscle strength. However, for the motor action of knee flexion and extension in the concentric and eccentric phases in female soccer players, the absolute and relative reliability for peak muscle strength with FEMD has not yet been demonstrated.

Considering that most FEMD studies have been performed on young male college students and little evidence exists in women and none in female soccer players, the aim of this study was to analyze the absolute and relative test–retest reliability of maximal muscle strength in knee flexion–extension as measured using a FEMD in a group of young competitive female soccer players. The research hypothesis is that this test will be a reliable method for the evaluation of concentric and eccentric strength in knee flexion and extension, and the information obtained can be used to better control muscle strength and sports performance.

## 2. Materials and Methods

### 2.1. Study Design

A repeated-measure design was used to determine the reliability of a knee FLE-EXT peak muscle strength test with a FEMD. Participants attended 2 familiarization sessions (at least 48 h apart); the first session was used to assess anthropometry and to familiarize participants with the measurement procedures and FEMD. Participants then began the experimental trials. On each of these days, participants performed maximal muscle strength assessments for the knee musculature. Each assessment was performed in the Physical Activity Sciences Laboratory at the Universidad de las Américas Concepción Chile. All assessments were performed at the same time of day (±1 h) for each participant and below uniform standard conditions of time (±1 h), temperature (≈21 °C), and humidity (≈60% humidity).

### 2.2. Participants

Seventeen professional female soccer players (age = 18.64 ± 0.62 years; weight = 54.72 ± 7.03 kg; height = 1.58 ± 0.04 m; BMI = 21.62 ± 2.70 $kg/m^2$; skeletal muscle mass = 22.67 ± 2.56 kg; body fat mass = 13.49 ± 3.50 kg; body fat percentage = 24.18 ± 4.14%) gave their consent to participate in the research study. The participants (a) did not present any musculoskeletal pathology in the lower limbs, (b) had at least 3 years of experience in sports practice, and (c) attended more than 85% of the team's training sessions. Before giving their assent or writing parental or legal guardian approval, the study participants were all told about the purpose, nature, and hazards of the experimental technique. The study protocol was approved by the Ethics and Research Committee of the Universidad Católica de la Santísima Concepción No. 01/2024 (approved 1 April 2024) and was conducted following the Declaration of Helsinki [23].

### 2.3. Anthropometric Measurement

Weight and body composition were assessed with a multifrequency octopolar BIA analyzer (model InBody 120, Arlington Heights, IL, USA) at a measurement range of 5 to 250 kg and an accuracy of 0.1 kg).

### 2.4. Materials

Peak muscle strength was assessed with a FEMD (Dynasystem, Model Research, Granada, Spain) with a precision of 3 mm for the displacement, 100 g for the detected load, a sampling frequency of 1000 Hz, and a range of velocities between 0.05 $m \cdot s^{-1}$ and 2.80 $m \cdot s^{-1}$. Its core control precisely regulates both force and linear velocity using a 2000 W electric motor. A wide variety of movements can be assessed in different anatomical planes, and the device can deliver a wide variety of stimuli (isokinetic, isotonic, elastic, isometric, inertial, eccentric, and vibratory) for the assessment of muscle strength in its different manifestations. The displacement and speed data are collected with a 2500 ppr encoder attached to the roller. The data from the different sensors are obtained at a frequency of 1 kHz. The user applies forces to a rope wound on a roller. A load cell detects the tension applied to the rope, and the resulting signal is passed to an analog to digital converter with 12-bit resolution.

### 2.5. Familiarization Protocol

Participants underwent a 45 min FEMD familiarization session. Familiarization consisted of using a load of 5% of body weight as the load for the knee FLE exercises and 10% for knee extension at a displacement velocity of 0.4 $m \cdot s^{-1}$.

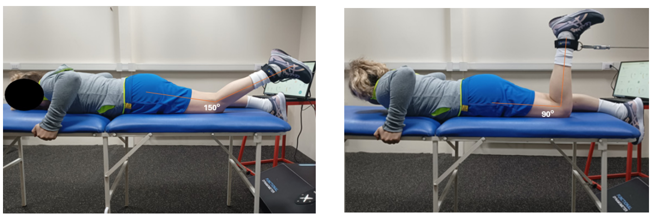
### 2.6. Assessment of Muscle Strength

Prior to the assessment of muscle strength, a general warm-up was performed for (a) 5 min on a stationary bicycle at 60% of the heart rate reserve and 10 min of joint mobility in the lower limbs, barbell squats, and hamstring bridges and (b) 10 min of a specific warm-up of the submaximal test at the selected speed with 2 sets of 3 repetitions and a 3 min break between sets. A load of 5% of body weight was used as the load for the warm-up exercises of the flexor muscles and 10% for the knee extensor muscles. Peak muscle force data were measured with a FEMD. Knee muscle strength was evaluated with the following movements: knee EXT and knee FLE. Participants were asked to exert their maximum effort. Each movement was evaluated at a speed of 0.4 $m \cdot s^{-1}$ unilaterally, recording peak muscle strength values using software provided by the FEMD in the CON with the movement to the end of ROM and an ECC that attempts to retain the movement backwards.

The range of motion of the knee was determined with a goniometer, allowing a functional range for each player of extension from 90° to 0° and flexion from 150° to 90°. Subsequently, the warm-up was performed in the same manner as in the familiarization sessions. Assessments were performed in the seated position for knee extension (Figure 1) and prone for knee flexion (Figure 2). A series of 3 repetitions was performed for each of the movements evaluated. The order of strength assessment was as follows: (1) right knee extension, (2) left knee extension, (3) right knee flexion, and (4) left knee flexion. The participants were evaluated in the laboratory of Physical Activity Sciences of the University of the Américas, Concepción, Chile.


(**a**) (**b**)

**Figure 1.** Evaluation of maximal strength in knee extensor muscles: (**a**) initial position; (**b**) final position.




(**a**) (**b**)

**Figure 2.** Evaluation of maximal strength in knee flexor muscles: (**a**) initial position; (**b**) final position.

### 2.7. Statistical Analysis

Means and standard deviations (SDs) were used to report the descriptive statistics collected. The normal distribution of the data was analyzed using the Shapiro–Wilk statistical model ($p > 0.05$). The paired samples *t*-test and the effect size (ES) of the standardized mean differences for repeated samples were used to compare the magnitude of the muscle force generated between both sessions. The criteria to interpret the magnitude of the ES were the following: very large (>2.00), large (1.20–2.00), moderate (0.60–1.19), small (0.2–0.59), and null (<0.20) [24]. The absolute reliability was measured using the standard error of measurement (SEM); in addition, the coefficient of variation (CV) and the relative reliability were evaluated using the intraclass correlation coefficient (ICC) model. The following criteria were used to determine high (CV ≤ 5%) and acceptable (CV ≤ 10%) reliability [25]. Relative reliability (ICC) was classified as values close to 0.9 (extremely high reliability), 0.7 (very high), 0.5 (high), 0.3 (moderate), and 0.1 (low) [26]. Bland–Altman plots were used to quantify systematic bias and 95% limits of agreement between the test and retest [27]. The heteroscedasticity of errors in Bland–Altman plots was defined as a coefficient of determination ($R^2 > 0.1$) [28]. Pearson's correlation coefficient was used to calculate the correlation of all peak muscle strength measurements between both testing sessions. The criteria for interpreting the magnitude of r were perfect (1.00), almost perfect (0.90–0.99), very large (0.70–0.89), large (0.50–0.69), moderate (0.30–0.49), small (0.10–0.29), and null (0.00–0.09) [29]. For all statistical model calculations, a 95% confidence interval was used in their analysis. Statistical significance was accepted at a *p*-value < 0.05. All reliability analyses were performed using a custom spreadsheet [24], while other statistical model analyses were performed using JASP software (version 0.16.4).

## 3. Results

No significant differences were found ($p > 0.05$), and null ES (ES < 0.14) were detected in the measures of maximum muscle strength in the right and left knee extensors and flexors in their concentric or eccentric phases. In the test–retest reliability measures, acceptable absolute reliability and extremely high relative reliability were obtained for all peak muscle strength assessments, as presented in Table 1.

**Table 1.** Evaluation of peak force in extension and flexion of the right knee in the concentric and eccentric phases.

| | Mean ± SD (N) | | *p*-Value | ES | SEM | CV% | ICC |
|---|---|---|---|---|---|---|---|
| | Test | Retest | | | (95% CI) | (95% CI) | (95% CI) |
| Right knee extension | | | | | | | |
| Concentric | 175.07 ± 63.99 | 171.24 ± 56.59 | 0.43 | 0.06 | 14.85 (10.87–23.42) | 8.13 (6.06–12.37) | 0.95 (0.85–0.98) |
| Eccentric | 253.62 ± 85.53 | 265.14 ± 84.72 | 0.34 | 0.14 | 24.59 (25.76–52.65) | 13.34 (6.67–13.97) | 0.85 (0.64–0.94) |
| Left knee extension | | | | | | | |
| Concentric | 159.33 ± 50.17 | 165.31 ± 47.96 | 0.29 | 0.12 | 16.17 (12.04–24.60) | 9.96 (7.42–15.16) | 0.90 (0.76–0.96) |
| Eccentric | 261.36 ± 98.36 | 264.85 ± 95.19 | 0.59 | 0.04 | 18.89 (14.07–28.74) | 7.18 (5.35–10.92) | 0.97 (0.91–0.99) |
| Right knee flexion | | | | | | | |
| Concentric | 86.69 ± 25.17 | 89.57 ± 24.57 | 0.21 | 0.11 | 6.51 (4.85–9.91) | 7.39 (5.50–11.24) | 0.94 (0.85–0.98) |
| Eccentric | 162.17 ± 45.25 | 175.85 ± 54.20 | 0.14 | 0.02 | 14.62 (10.89–22.25) | 8.65 (5.35–13.16) | 0.93 (0.81–0.97) |
| Left knee flexion | | | | | | | |
| Concentric | 87.46 ± 30.45 | 91.76 ± 29.98 | 0.17 | 0.14 | 8.88 (6.61–13.52) | 9.91 (7.38–15.08) | 0.92 (0.80–0.97) |
| Eccentric | 158.51 ± 47.07 | 173.94 ± 53.56 | 0.12 | 0.13 | 16.05 (11.95–24.42) | 9.65 (7.19–14.69) | 0.91 (0.77–0.97) |

N: newton; *p*-value: significance level; SD: standard deviation; ES: Cohen's d effect size; SEM: standard error of measurement; CV%: coefficient of variation; ICC: intraclass correlation coefficient; 95% CI: 95% confidence interval; s: seconds.

The Bland–Altman plots reveal a low systematic bias (−15.43–3.825 N) for the assessment of peak muscle strength in right knee extension (RKE), peak muscle strength in left knee extension (LKE), peak muscle strength in right knee flexion (RKF), and peak muscle strength in left knee flexion (LKF) in the concentric and eccentric phase, as well as a coefficient of determination of $R^2$ = 0.223−0.018, as shown in Figure 3.

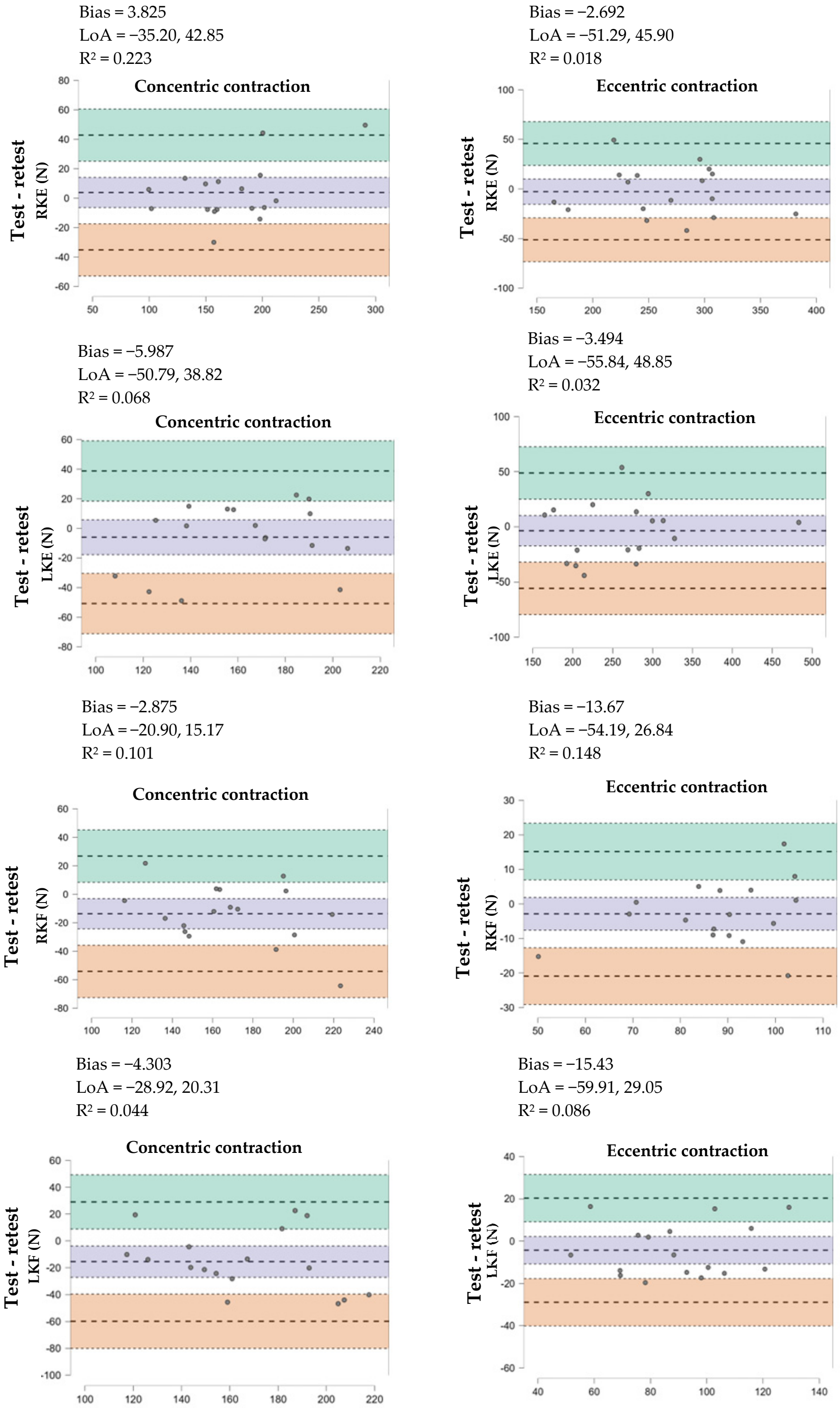



**Figure 3.** Bland–Altman plots of test–retest for peak muscle strength in right knee extension (RKE), peak muscle strength in left knee extension (LKE), peak muscle strength in right knee flexion (RKF), and peak muscle strength in left knee flexion (LKF) in the concentric and eccentric phases in both test sessions during maximal muscle strength assessment using a FEMD.

The magnitude r was almost perfect (0.926) for RKE and very large for LKE, RKF, and LKF (0.756–0.848) in the concentric phase. In the eccentric phase, the magnitude r was almost perfect for RKE and KLE (0.901–0.941) and very large for RKF and LKF (0.779–0.826), and all results were highly significant ($p$ = 0.001), as can be seen in Figure 4.

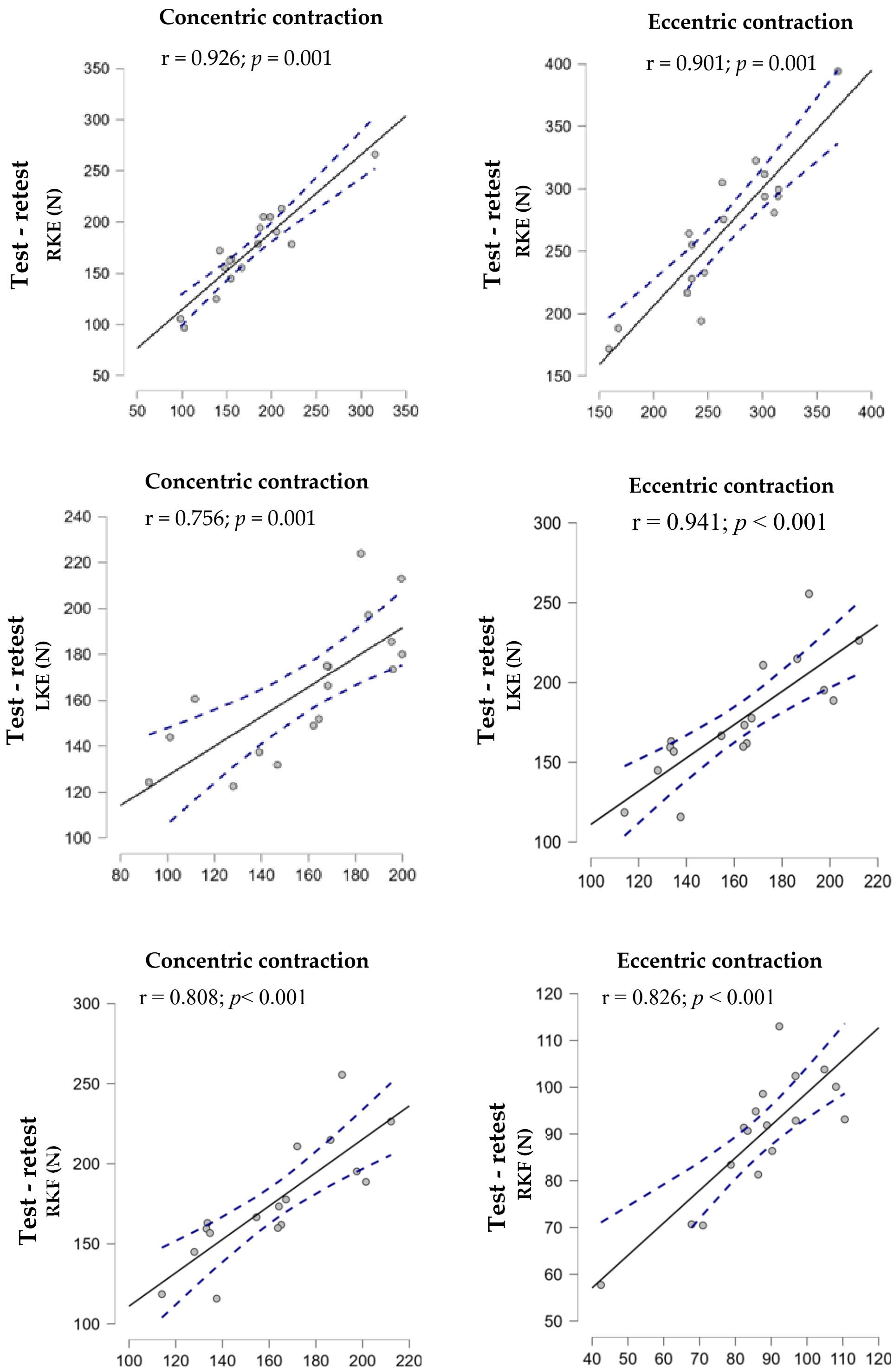



**Figure 4.** *Cont*.

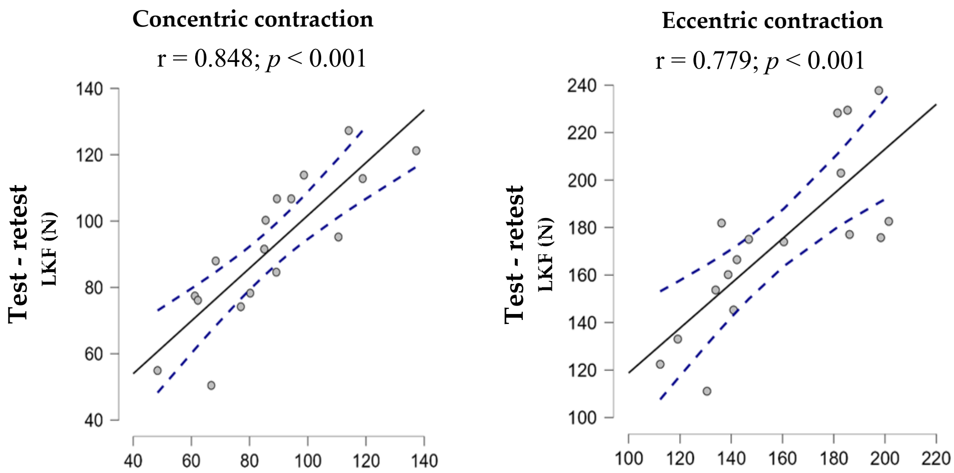



**Figure 4.** Relationship between peak muscle strength in right knee extension (RKE), peak muscle strength in left knee extension (LKE), peak muscle strength in right knee flexion (RKF), and peak muscle strength in left knee flexion (LKF) in the concentric and eccentric phases in both test sessions during FEMD-controlled peak muscle strength assessment. The small circles are the analyzed muscle force loads, the central line is the graph of the Pearson correlation model, the blue dashed lines are the 95% confidence interval of the model provided by the JASP statistical package.

## 4. Discussion

The purpose of this study was to analyze the absolute and relative test–retest reliabilities of peak muscle strength in knee flexion–extension controlled using a FEMD in a group of young female soccer players. This study reported consistent to acceptable reliability in all strength evaluations, with no significant variation found between the two sessions measuring peak muscle strength. The results of our study confirm that the assessment of peak muscle strength in knee flexion and extension, both concentrically and eccentrically with FEMD is reliable.

For many decades, knee flexion and extension strength have been evaluated using isokinetic devices, which are considered the gold standard for strength assessment [30,31]. However, multi-joint isokinetic devices have emerged, and these devices can be used to reliably and effectively evaluate and train specific muscle activation patterns through various stimuli, as demonstrated by the use of the FEMD [32]. In previous studies, FEMDs have proven to be reliable for assessing trunk strength in flexion–extension and rotation [33–35], as well as shoulder [36] and hip strength [17]. Similar results were found in all studies that examined the reliability of the FEMD for the assessment of strength; however, in our study, we found higher absolute reliability values than those found in the trunk and shoulder flexion and extension studies [35,36]. The assessment of peak muscle strength in knee flexion and extension is an assessment that has been performed with a FEMD, and the population evaluated is female soccer players, a population that has not been studied with FEMDs, since most of the research previously conducted with FEMDs was in young university students.

Similar results to those of our study were obtained in the level of reliability in the study by Sánchez-Sánchez et al. [22], which analyzed the peak muscle strength for the hamstring exercise protocol with eccentric swing at a displacement velocity of 0.4 $m{\cdot}s^{-1}$, equal to that of this study. In the scientific literature, speed in isokinetic tests has been examined [37,38]. Research indicates that when evaluating strength in the various isokinetic tests, velocities less than 0.6 $m{\cdot}s^{-1}$ are often the most accurate [38]. Although it is possible that the concentric phase of movements is not practiced as frequently as the concentric phase, which could explain the greater impact of learning in the eccentric phase [39].

These new functional electromechanical devices need an appropriate and detailed familiarization process to ensure the repeatability of measurements in the assessment of different manifestations of strength, especially with variable movements [22]. In a study by Koopmann et al. [40], carried out on young handball players, handball throwing skills showed poor reliability when no familiarization process was carried out to ensure the learning of the athletic movement to be assessed.

The peak strength, speed, and power of the musculature may be better understood through the study of a trustworthy evaluation methodology using FEMDs. The previously assessed procedures exhibited dependable values, enabling the utilization of the evaluation circumstances that corresponded to each study across all of them. While this study proved the good reliability of the FEMD, future research should take into consideration some limitations. Since training history at other levels of competition alternating in games was not considered, it is not possible to generalize our findings to all athletes in other sports. Future studies should be initiated that analyze different motor gestures of each sport in different populations and levels of competition.

## 5. Conclusions

The main result of our study reports that the evaluation of peak muscle strength in knee flexion and extension, both concentrically and eccentrically with FEMDs, has relative and absolute reliability when evaluating professional female soccer players. This makes it easier to track the progress and development of female footballers by providing another more affordable option for recording various manifestations of muscle strength and what it implies for the development of skills specific to the sport.

**Author Contributions:** Conceptualization, O.A.-R. and D.U.-D.; methodology, O.A.-R.; software, G.M.-B.; validation, A.R.-P. and L.-J.C.-R.; formal analysis, O.A.-R.; investigation, S.A.-S.; data curation, F.G.-R.; writing—original draft preparation, O.A.-R.; writing—review and editing, D.U.-D.; visualization, S.A.-S.; supervision, L.-J.C.-R.; project administration, D.U.-D. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Institutional Review Board Statement:** This study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of the Universidad Católica de la Santísima Concepción No. 01/2024, approved on 1 April 2024.

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in this study.

**Data Availability Statement:** All relevant data are within the manuscript. The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

**Acknowledgments:** Center for Nutritional Care, University of the Americas, and Karla Cárdenas-Ovando.

**Conflicts of Interest:** The authors declare no conflicts of interest.

## References

1. McBride, L.; James, R.S.; Alsop, S.; Oxford, S.W. Intra and Inter-Rater Reliability of a Novel Isometric Test of Neck Strength. *Sports* **2023**, *11*, 2. [CrossRef] [PubMed]
2. Venegas-Carro, M.; Kramer, A.; Moreno-Villanueva, M.; Gruber, M. Test–Retest Reliability and Sensitivity of Common Strength and Power Tests over a Period of 9 Weeks. *Sports* **2022**, *10*, 171. [CrossRef] [PubMed]
3. Barjaste, A.; Mirzaei, B. The periodization of resistance training in soccer players: Changes in maximal strength, lower extremity power, body composition and muscle volume. *J. Sports Med. Phys. Fit.* **2018**, *58*, 1218–1225. [CrossRef] [PubMed]
4. Negra, Y.; Chaabene, H.; Hammami, M.; Hachana, Y.; Granacher, U. Effects of High-Velocity Resistance Training on Athletic Performance in Prepuberal Male Soccer Athletes. *J. Strength Cond. Res.* **2016**, *30*, 3290–3297. [CrossRef]
5. Magallanes, A.; Magallanes, C.; Parodi, A.; González-Ramírez, A. Transfer of a resistance training program to sprinting and vertical jump in youth soccer players: Squats vs. lunges. *Retos* **2022**, *42*, 972–979. [CrossRef]
6. Datson, N.; Drust, B.; Weston, M.; Jarman, I.H.; Lisboa, P.J.; Gregson, W. Match Physical Performance of Elite Female Soccer Players during International Competition. *J. Strength Cond. Res.* **2017**, *31*, 2379–2387. [CrossRef]
7. Pecci, J.; Muñoz-López, A.; Jones, A.P.; Sañudo, B. Effects of 6 weeks in-season flywheel squat resistance training on strength, vertical jump, change of direction and sprint performance in professional female soccer players. *Biol. Sport* **2023**, *40*, 521–529. [CrossRef]

8. Brígido-Fernández, I.; García-Muro San José, F.; Charneco-Salguero, G.; Cárdenas-Rebollo, J.M.; Ortega-Latorre, Y.; Carrión-Otero, O.; Fernández-Rosa, L. Knee Isokinetic Profiles and Reference Values of Professional Female Soccer Players. *Sports* **2022**, *10*, 204. [CrossRef]
9. McFarland, I.T.; Dawes, J.J.; Elder, C.L.; Lockie, R.G. Relationship of Two Vertical Jumping Tests to Sprint and Change of Direction Speed among Male and Female Collegiate Soccer Players. *Sports* **2016**, *4*, 11. [CrossRef]
10. Fédération Internationale de Footbal Association. Women's Football across the National Associations. 2017. Available online: https://www.uefa.com/MultimediaFiles/Download/OfficialDocument/uefaorg/Women'sfootball/02/43/13/56/2431356_DOWNLOAD.pdf (accessed on 1 May 2020).
11. Randell, R.K.; Clifford, T.; Drust, B.; Moss, S.L.; Unnithan, V.B.; De Ste Croix, M.B.A.; Datson, N.; Martin, D.; Mayho, H.; Carter, J.M.; et al. Physiological Characteristics of Female Soccer Players and Health and Performance Considerations: A Narrative Review. *Sports Med.* **2021**, *51*, 1377–1399. [CrossRef]
12. Pardos-Mainer, E.; Lozano, D.; Torrontegui-Duarte, M.; Cartón-Llorente, A.; Roso-Moliner, A. Effects of Strength vs. Plyometric Training Programs on Vertical Jumping, Linear Sprint and Change of Direction Speed Performance in Female Soccer Players: A Systematic Review and Meta-Analysis. *Int. J. Environ. Res. Public Health* **2021**, *18*, 401. [CrossRef] [PubMed]
13. Chirosa-Ríos, L.J.; Chirosa-Ríos, I.J.; Martínez-Marín, I.; Román-Montoya, Y.; Vera-Vera, J.F. The Role of the Specific Strength Test in Handball Performance: Exploring Differences across Competitive Levels and Age Groups. *Sensors* **2023**, *23*, 5178. [CrossRef]
14. del-Cuerpo, I.; Jerez-Mayorga, D.; Delgado-Floody, P.; Morenas-Aguilar, M.; Chirosa-Ríos, L. Test–Retest Reliability of the Functional Electromechanical Dynamometer for Squat Exercise. *Int. J. Environ. Res. Public Health* **2023**, *20*, 1289. [CrossRef] [PubMed]
15. Jerez-Mayorga, D.; Delgado-Floody, P.; Intelangelo, L.; Campos-Jara, C.; Arias-Poblete, L.; García-Verazaluce, J.; Garcia-Ramos, A.; Chirosa, L.J. Behavior of the muscle quality index and isometric strength in elderly women. *Physiol. Behav.* **2020**, *227*, 113145. [CrossRef]
16. Rodriguez-Perea, A.; Jerez-Mayorga, D.; García-Ramos, A.; Martínez-García, D.; Chirosa-Ríos, L. Reliability and concurrent validity of a functional electromechanical dynamometer device for the assessment of movement velocity. *J. Sports Eng. Technol.* **2021**, *235*, 176–181. [CrossRef]
17. Vega, E.C.; Jerez-Mayorga, D.; Payer, R.M.; Jara, C.C.; Guzman-Guzman, I.; Ponce, A.R.; Chirosa, L.J. Validity and reliability of evaluating hip abductor strength using different normalization methods in a functional electromechanical device. *PLoS ONE* **2018**, *13*, e0202248. [CrossRef]
18. Andrades-Ramírez, O.; Ulloa-Díaz, D.; Alfaro Castillo, B.; Arroyo-Jofré, P.; Castillo-Paredes, A.; Chirosa-Ríos, L. Test–Retest Reliability of an Isometric and Isometric/Vibratory Muscular Strength Protocol with Functional Electro-Mechanical Dynamometry. *Sports* **2024**, *12*, 175. [CrossRef]
19. Baena-Raya, A.; Díez-Fernández, D.; García-Ramos, A.; Soriano-Maldonado, A.; Rodríguez-Pérez, M. Concurrent validity and reliability of a functional electromechanical dynamometer to assess isometric mid-thigh pull performance. *J Sports Eng. Technol.* **2021**, *237*, 197–204. [CrossRef]
20. Jerez-Mayorga, D.; Huerta-Ojeda, A.; Chirosa-Ríos, L.; Guede-Rojas, F.; Guzmán-Guzmán, I.; Intelangelo, L.; Miranda-Fuentes, C.; Delgado-Floody, P. Test-Retest Reliability of Functional Electromechanical Dynamometer on Five Sit-to-Stand Measures in Healthy Young Adults. *Int. J. Environ. Res. Public Health* **2021**, *18*, 6829. [CrossRef]
21. Martinez-Garcia, D.; Rodriguez-Perea, A.; Barboza, P.; Ulloa-Díaz, D.; Jerez-Mayorga, D.; Chirosa, I.; Chirosa-Ríos, L. Reliability of a standing isokinetic shoulder rotators strength test using a functional electromechanical dynamometer: Effects of velocity. *PeerJ* **2020**, *8*, e9951. [CrossRef]
22. Sánchez-Sánchez, A.; Chirosa-Ríos, L.; Chirosa-Ríos, I.; García-Vega, A.J.; Jerez-Mayorga, D. Test-retest reliability of a functional electromechanical dynamometer on swing eccentric hamstring exercise measures in soccer players. *PeerJ* **2021**, *9*, e11743. [CrossRef] [PubMed]
23. World Medical Association. World Medical Association Declaration of Helsinki: Ethical principles for medical research involving human subjects. *JAMA* **2013**, *310*, 2191–2194. [CrossRef] [PubMed]
24. Hopkins, W. Spreadsheets for analysis of validity and reliability. *Sportscience* **2015**, *21*, 36–44. Available online: https://sportsci.org/2015/ValidRely.htm (accessed on 20 August 2024).
25. Weir, J.P. Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM. *J. Strength Cond. Res.* **2005**, *19*, 231–240.
26. Brady, C.; Harrison, A.; Comyns, T. A review of the reliability of biomechanical variables produced during the isometric mid-thigh pull and isometric squat and the reporting of normative data. *Sports Biomech.* **2020**, *19*, 1–25. [CrossRef] [PubMed]
27. Boehringer, S.; Whyte, D. Validity and test-retest reliability of the 1080 quantum system for bench press exercise. *J. Strength Cond. Res.* **2019**, *33*, 3242–3251. [CrossRef]
28. Atkinson, G.; Nevill, A.M. Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. *Sports Med.* **1998**, *26*, 217–238. [CrossRef]
29. Hopkins, W.; Marshall, S.; Batterham, A.; Hanin, J. Progressive statistics for studies in sports medicine and exercise science. *Med. Sci. Sports Exerc.* **2009**, *41*, 3–13. [CrossRef]
30. Cockburn, E.; Hayes, P. Test-retest reliability of isokinetic concentric knee extension and flexion. *Br. J. Sports Med.* **2010**, *44*, 26. [CrossRef]

31. Maffiuletti, N.A.; Bizzini, M.; Desbrosses, K.; Babault, N.; Munzinger, U. Reliability of knee extension and flexion measurements using the Con-Trex isokinetic dynamometer. *Clin. Physiol. Funct. Imaging* **2007**, *27*, 346–353. [CrossRef] [PubMed]
32. Zeevi, D.; Müller, S. Multiple-Joint Isokinetic Dynamometry: A Critical Review. *J. Strength Cond. Res.* **2020**, *34*, 587–601. [CrossRef]
33. Rodríguez-Perea, A.; Chirosa-Ríos, L.; Martínez-García, D.; Ulloa-Díaz, D.; Guede Rojas, F.; Jerez-Mayorga, D.; Chirosa-Ríos, I. Reliability of isometric and isokinetic trunk flexor strength using a functional electromechanical dynamometer. *PeerJ* **2019**, *7*, e7883. [CrossRef]
34. Reyes-Ferrada, W.; Rodríguez-Perea, Á.; Chirosa-Ríos, L.; Martínez-García, D.; Jerez-Mayorga, D. Muscle Quality and Functional and Conventional Ratios of Trunk Strength in Young Healthy Subjects: A Pilot Study. *Int. J. Environ. Res. Public Health* **2022**, *19*, 12673. [CrossRef] [PubMed]
35. Rodríguez-Perea, A.; Jerez-Mayorga, D.; Morenas-Aguilar, M.; Martínez-García, D.; Chirosa-Ríos, I.; Chirosa-Ríos, L.; Reyes-Ferrada, W. Influence of Sex and Dominant Side on the Reliability of Two Trunk Rotator Exercises. *Appl. Sci.* **2023**, *13*, 2441. [CrossRef]
36. García-Buendía, G.; Rodríguez-Perea, Á.; Chirosa-Ríos, I.; Chirosa-Ríos, L.J.; Martínez-García, D. Reliability of Dynamic Shoulder Strength Test Battery Using Multi-Joint Isokinetic Device. *Sensors* **2024**, *24*, 3568. [CrossRef]
37. Hadzic, V.; Ursej, E.; Kalc, M.; Dervisevic, E. Reproducibility of shoulder short range of motion isokinetic and in isometric strength testing. *J. Exerc. Sci. Fit.* **2012**, *10*, 83–89. [CrossRef]
38. Zanca, G.; Oliveira, A.B.; Saccol, M.F.; Mattiello-Rosa, S.M. Isokinetic dynamometry applied to shoulder rotators–Velocity limitations in eccentric evaluations. *J. Sci. Med. Sport* **2011**, *14*, 541–546. [CrossRef] [PubMed]
39. Nugent, E.P.; Snodgrass, S.J.; Callister, R. The effect of velocity and familiarization on the reproducibility of isokinetic dynamometry. *Isokinet. Exerc. Sci.* **2015**, *23*, 205–214. [CrossRef]
40. Koopmann, T.; Lath, F.; Büsch, D.; Schorer, J. Predictive Value of Technical Throwing Skills on Nomination Status in Youth and Long-Term Career Attainment in Handball. *Sports Med.Open* **2022**, *8*, 6. [CrossRef]