symmetry

MDPI

Article

The Test–Retest Reliability of a Belt-Fixated Dynamometer for Assessing Maximal Knee Strength, Inter-Limb Asymmetries, and Hamstring–Quadriceps Ratios

Nenad Nedović [1], Stevan Jovanović [1], Danilo Vujičić [1], Chris Bishop [2] and Žiga Kozinc [3,*]

[1] Academy of Applied Studies Belgrade, College of Health Sciences, 11000 Belgrade, Serbia; nenad.nedovic@assb.edu.rs (N.N.)
[2] London Sport Institute, Faculty of Science and Technology, Middlesex University, London NW4 1RL, UK
[3] Department of Kinesiology and Physical Education, Faculty of Health Sciences, University of Primorska, Polje 42, SI-6310 Izola, Slovenia
* Correspondence: ziga.kozinc@fvz.upr.si

Abstract: Evaluating maximal strength, inter-limb asymmetries, and the hamstring-to-quadriceps (HQ) ratio is essential for identifying strength deficits in athletes. This cross-sectional study assessed the test–retest (inter-visit) reliability of the EasyForce dynamometer for knee extension and flexion strength in 21 young healthy participants (11 women and 10 men; age = 19.4 ± 0.7 years). The dynamometer demonstrated excellent relative reliability, with ICC values of 0.99 for knee extension and 0.95–0.98 for knee flexion. Absolute reliability was also acceptable (typical error = 5.63–16.44 N; coefficient of variation = 3.94–6.80%). Reliability for inter-limb asymmetries (ICC = 0.90) and HQ ratios (ICC = 0.91–0.92) was good to excellent. Agreement for inter-limb asymmetry direction between visits was excellent for knee extension (κ = 0.90) and substantial for knee flexion (κ = 0.71). These findings suggest that EasyForce is reliable for assessing muscle strength, inter-limb asymmetries, and HQ ratios in physically active adults. Future research should explore the broader applicability of EasyForce in muscle strength assessment, particularly for professional athletes and during rehabilitation.

Keywords: knee joint strength; reliability; injury prevention; symmetry

check for updates

Citation: Nedović, N.; Jovanović, S.; Vujičić, D.; Bishop, C.; Kozinc, Ž. The Test–Retest Reliability of a Belt-Fixated Dynamometer for Assessing Maximal Knee Strength, Inter-Limb Asymmetries, and Hamstring–Quadriceps Ratios. *Symmetry* **2024**, *16*, 1541. https://doi.org/10.3390/sym16111541

Academic Editor: Vilfredo De Pascalis

Received: 25 October 2024
Revised: 15 November 2024
Accepted: 17 November 2024
Published: 18 November 2024

1. Introduction

Strength measurements are essential in both clinical and athletic settings as they offer critical insights into an individual's muscle function, injury risk, and rehabilitation progress [1–3]. Among these measurements, knee strength is frequently evaluated, likely due to the knee's critical role in athletic activities like decelerating the body's center of mass during movements like jumping and landing or daily functions like climbing stairs [4–7]. In addition to assessing maximal strength (peak force or peak torque during maximal voluntary contraction), understanding inter-limb asymmetries and, in the case of the knee joint, the hamstring-to-quadriceps (HQ) ratio is essential for identifying strength imbalances that could potentially lead to injuries in athletes. Recent evidence indicates a strong interest in inter-limb asymmetry assessment because of its potential connection with both injury and performance [8–10]. However, there is a need to standardize methodology and analysis to improve the interpretation, adoption, and implementation of inter-limb asymmetry testing and related interventions that may be required for athlete populations [9].

To facilitate the effective use of strength measurements in athletic and clinical settings, reliable assessment procedures are needed. Various methods, such as isokinetic dynamometry, isometric testing, and hand-held dynamometry (HHD), are employed to measure muscle strength [11,12]. HHD is particularly valued for its convenience and portability. While studies generally support the reliability of HHD for muscle strength assessments, inconsistencies remain, especially when measuring stronger muscle groups like knee extensors and flexors, where examiner strength can influence results [13,14]. Considering the substantial influence of belt stabilization on the mean values and reliability of knee strength assessments [15], further research is essential to compare different applications of belt stabilization.

The EasyForce dynamometer is an innovative dynamometer equipped with a belt-stabilized design, known for its reliability, user-friendly interface, and affordability. Previous studies on EasyForce, such as those by Kozinc et al. [16] and Trajković et al. [17], have provided valuable insights into its functionality and reported moderate-to-good reliability and validity scores. Specifically, Trajković et al. [17] found inter-rater reliability for knee tasks to be moderate to good, with intraclass correlation coefficient (ICC) values ranging from 0.65 to 0.83. Kozinc et al. [16] demonstrated excellent relative test–retest reliability for knee joint measurements, with ICC values greater than 0.90; however, the absolute reliability was not acceptable with an error exceeding 10% of the mean value. These findings suggest that despite the stabilization provided by the belt, significant variation across raters and visits may be present. To address this variation, the authors of some previous studies have suggested attaching the dynamometer to an immovable anchor instead of having the examiner hold it [18].

In addition, previous studies have not fully explored all aspects of belt-stabilized dynamometer (such as EasyForce) performance, particularly the reliability of measuring inter-limb asymmetry or the HQ ratio. Previous findings indicate that inter-limb asymmetry scores for muscle strength and power exhibit lower reliability compared to raw values [9,19,20], highlighting the critical importance of establishing reliable methods for assessing inter-limb asymmetries, if the data are to be usable to help guide decision-making. A study by Bishop et al. [21] has already demonstrated that isokinetic assessments, including peak torque of knee extensors and flexors, intra-limb ratio, and inter-limb asymmetry, can distinguish between professional and academy soccer players. Also, it is likely that unilateral tasks offer a more accurate measure of force generation, as the load is not distributed or compensated across both limbs [22]. Inter-limb asymmetries and HQ ratio can be applied in sports training to spot and address strength imbalances, allowing practitioners to create targeted programs that help reduce injury risk, while in rehabilitation, tracking inter-limb asymmetry over time can ensure balanced strength development, supporting safer and more effective recovery [23–25].

This study aimed to evaluate the reliability of the EasyForce dynamometer in measuring knee extension and flexion, both within a single visit and across multiple visits. We hypothesized that EasyForce would demonstrate excellent reliability for measuring force, good reliability for assessing inter-limb asymmetries, and good reliability for assessing the hamstrings-to-quadriceps (HQ) ratio. The findings of this study are crucial as they will help establish the belt-stabilized HHD as a reliable tool for both clinical assessments and research, ensuring accurate detection of strength imbalances and potential injury risks.

2. Materials and Methods

2.1. Participants

The required sample size was determined based on a previous study assessing knee extensor and flexor force [16] in which all test–retest ICC coefficients were greater than 0.90. A priori power analysis indicated that for an expected ICC of 0.90, with a desired precision of 0.2, an alpha level of 0.05, and a statistical power of 0.90, a minimum of 15 participants was required [26]. To ensure even greater robustness of the results and account for possibly lower reliability in the case of inter-limb asymmetry and HQ ratios, we recruited 21 participants (11 women and 10 men; age = 19.4 ± 0.7 years; body height = 177.8 ± 8.6 cm; body mass = 71.0 ± 14.2 kg).

The participants were students of physiotherapy and were recruited as a convenience sample through social media, emailing, and personal networking. Participants were excluded from the study if they reported any pain in the knee, restrictions in active range of motion at the knee or hip range of motion (assessed visually by a physical therapist; at least 90° of flexion for both), or prior injury in the lower limb. Participants gave their informed consent before the experiment by signing consent forms. The study was approved by the Ethics Board of the Academy of Applied Studies Belgrade, College of Health Sciences.

2.2. Study Design

We conducted a repeated measures study to evaluate the test–retest reliability of the EasyForce dynamometer for assessing knee flexion and knee extension muscle strength (force), as well as HQ ratio and inter-limb asymmetries. The measurements were the same for both visits, which were spaced 5–7 days apart. Participants performed a 15 min warm-up, guided by a physical therapist. The warm-up included 5 min of light-intensity cycling on an indoor ergometer, followed by 5 min of static stretching and bodyweight resistance exercises such as lunges and squats.

Strength assessments were performed for each leg separately, while the order of tasks (knee extension and knee flexion) was randomly determined for each participant and maintained on the second visit. Participants performed 3 submaximal warm-up trials before each task, progressing from 50 to 90% of maximal effort. During the main trials, the participants were instructed to gradually reach maximal force over about 1–2 s and then maintain it for an additional 3–4 s, with verbal encouragement given throughout the tasks. A single examiner with a physiotherapy and kinesiology background conducted the assessments, while a second examiner recorded the values and managed the computer. The first examiner was blinded to the results during and between visits.

2.3. Measurement Procedures

Measurements using the EasyForce dynamometer were conducted in accordance with the manufacturer's guidelines. The dynamometer is a stand-alone device (no link to computer software), with the results displayed on the screen after the measurement.

The dynamometer records tension force continuously to the nearest 1 N, with the maximal capacity at 150 kg (1471 N). Measurement will automatically start when the force reaches 5 N for more than 0.5 s and end when the force drops to zero, displaying peak and average force values. The device must be reset before a new measurement, preventing small movements from affecting the results. For knee extension assessments (Figure 1A), participants sat on a table with their knees bent at 90°, hands resting on their thighs, and torso upright. The dynamometer was positioned 2 cm above the malleolus. For knee flexion assessments (Figure 1B), the participants were prone with their knees flexed at 90°, and the dynamometer was positioned similarly. The dynamometer was fixed with a belt to immovable wooden bars secured to the wall. Results for raw strength scores are presented in newtons (N) and the mean value from the two repetitions was considered. The results represent peak force, which is readily displayed on the device when the measurement is ended. Inter-limb asymmetries were calculated by calculating the difference between the left and right sides and dividing it by the mean value. HQ ratio was calculated as the ratio between knee flexion and knee extension force.

2.4. Statistical Analysis

The data are presented as means ± standard deviations. Reliability was assessed through a single-measures ICC with absolute agreement, accompanied by 95% confidence intervals (CI). The ICC values were interpreted as follows: values below 0.5 indicate poor reliability, values between 0.5 and 0.75 indicate moderate reliability, values between 0.75 and 0.9 indicate good reliability, and values above 0.90 indicate excellent reliability [27]. Absolute reliability was also evaluated by calculating the typical error (TE) and coefficient of variation (CV), with the following interpretations: poor reliability (CV > 10%), moderate reliability (CV = 5–10%), and good reliability (CV < 5%) [28]. To assess the agreement level for the direction of asymmetries across sessions and testing conditions, kappa coefficients were calculated. Agreement levels were interpreted as follows: 0.01–0.20 = slight; 0.21–0.40 = fair; 0.41–0.60 = moderate; 0.61–0.80 = substantial; and

0.81–0.99 = nearly perfect [29]. All analyses were carried out using SPSS statistical software (version 25.0, IBM: Armonk, NY, USA).

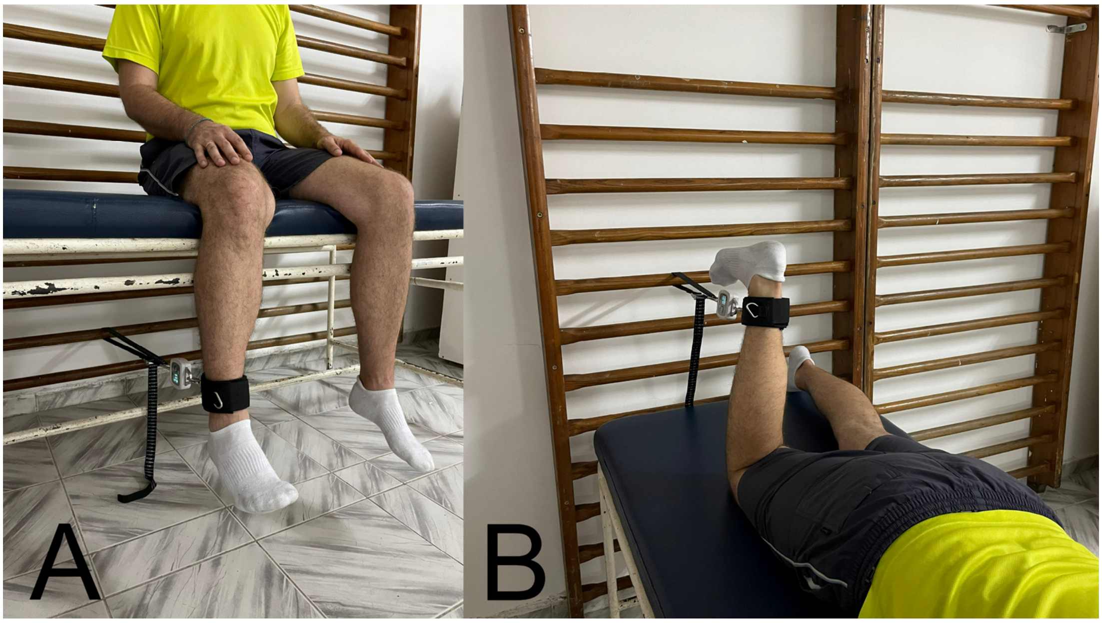

Figure 1. Participant position and dynamometer fixation for knee extension (**A**) and knee flexion (**B**) strength measurements.

3. Results

Table 1 contains all reliability analyses. Knee extension force demonstrated excellent reliability for both limbs. For the right knee extension, the ICC was 0.99 (95% CI: 0.97–0.99), with a TE of 12.98 N (95% CI: 9.93–18.74) and a CV of 3.94% (95% CI: 3.01–5.69). For the left knee extension, the ICC was 0.99 (95% CI: 0.97–0.99), with a TE of 16.44 N (95% CI: 12.58–23.74) and a CV of 4.82% (95% CI: 3.69–6.96). Inter-limb asymmetry in knee extension showed good-to-excellent relative reliability, with an ICC of 0.90 (95% CI: 0.78–0.96) and a TE of 6.44% (95% CI: 4.92–9.29).

Table 1. Test–retest reliability of all outcome measures.

Outcome Measure	Visit 1		Visit 2		Relative Reliability			Absolute Reliability					
	Mean	SD	Mean	SD	ICC	95% CI		TE	95% CI		CV	95% CI	
Knee extension, Right (N)	327.6	108.75	331.12	103.55	0.99	0.97	0.99	12.98	9.93	18.74	3.94	3.01	5.69
Knee extension, Left (N)	345.4	140.04	336.64	138.13	0.99	0.97	0.99	16.44	12.58	23.74	4.82	3.69	6.96
Asymmetry (%)	−3.03	19.84	0.53	19.66	0.90	0.78	0.96	6.44	4.92	9.29	/	/	/
Knee flexion, Right (N)	140.5	39.79	143.17	42.80	0.95	0.88	0.98	9.65	7.38	13.94	6.80	5.21	9.83
Knee flexion, Left (N)	138.3	42.32	140.81	44.17	0.98	0.96	0.99	5.63	4.31	8.14	4.04	3.09	5.83
Asymmetry (%)	1.29	14.11	1.22	13.32	0.90	0.78	0.96	4.45	3.40	6.42	/	/	/
HQ ratio, Right	0.43	0.10	0.44	0.10	0.92	0.82	0.97	0.03	0.02	0.04	6.90	5.28	9.97
HQ ratio, Left	0.44	0.08	0.44	0.08	0.91	0.80	0.96	0.02	0.02	0.04	5.65	4.32	8.15

SD: standard deviation; ICC: intraclass correlation coefficient; CI: confidence interval; TE: typical error; CV: coefficient of variation.

Knee flexion force exhibited good-to-excellent reliability. For right knee flexion, the ICC was 0.95 (95% CI: 0.88–0.98), with a TE of 9.65 N (95% CI: 7.38–13.94) and a CV of 6.80% (95% CI: 5.21–9.83). For left knee flexion, the ICC was 0.98 (95% CI: 0.96–0.99), with a TE of 5.63 N (95% CI: 4.31–8.14) and a CV of 4.04% (95% CI: 3.09–5.83). Inter-limb asymmetry in knee flexion showed good-to-excellent reliability, with an ICC of 0.90 (95% CI: 0.78–0.96) and a TE of 4.45% (95% CI: 3.40–6.42).

HQ ratios displayed good-to-excellent reliability. The ICC for the right side was 0.92 (95% CI: 0.82–0.97), with a TE of 0.03 (95% CI: 0.02–0.04) and a CV of 6.90% (95% CI: 5.28–9.97). For the left side, the ICC was 0.91 (95% CI: 0.80–0.96), with a TE of 0.02 (95% CI: 0.02–0.04) and a CV of 5.65% (95% CI: 4.32–8.15).

The agreement between inter-limb asymmetry direction was excellent for knee extension (κ = 0.90; $p < 0.001$) and substantial for knee flexion (κ = 0.71; $p = 0.001$). Figure 2 displays participant-by-participant inter-limb asymmetry scores, showing mostly consistent direction of inter-limb asymmetries across sessions.

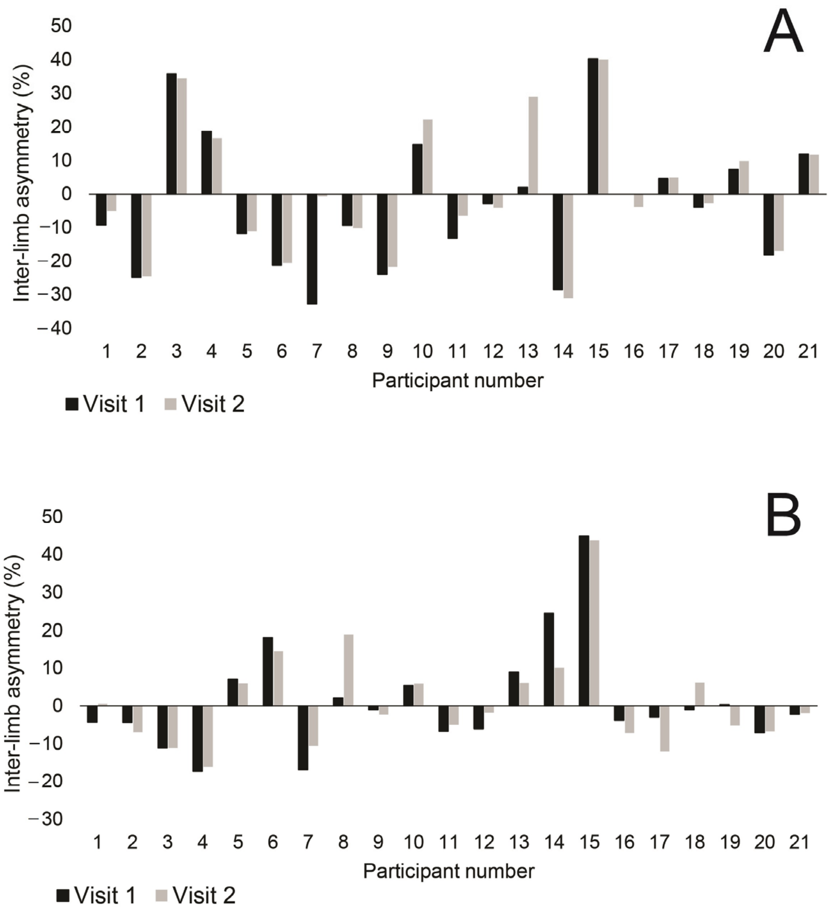

Figure 2. Inter-limb asymmetry values, shown separately for each participant for each visit for knee extensors (**A**) and knee flexors (**B**).

4. Discussion

This study aimed to evaluate the reliability of the EasyForce dynamometer in measuring knee extension and flexion strength (force), inter-limb asymmetries, and the HQ ratio. Our findings showed that the assessments using the EasyForce dynamometer demonstrated good-to-excellent relative and absolute reliability for both knee extension and knee flexion force, as well as inter-limb asymmetries and HQ ratio.

Consistent with previous reports on other handheld dynamometers [11,12], we found that the EasyForce dynamometer demonstrated high-to-excellent relative reliability for assessing knee extension and flexion strength. Compared to a previous EasyForce study [16], our absolute reliability scores (CV = 3.94–4.82%) showed a significant improvement (CV = 10.0–10.7%). We could explain this by the fact that we stabilized the dynamometer by fixing it to the wall, which could exclude the examiner's strength (among other factors) as a factor affecting the results [15]. Previous handheld dynamometers primarily measured push force [13] and required either handheld use or being positioned between a stabilizing belt and the participant's skin. Previous studies have shown higher CV values for both classic handheld dynamometers (21.3–42.5%) [30] and belt-stabilized handheld dynamometers (12.0–22.0%) [14], when assessing knee extension and flexion strength. Therefore, the approach adopted in this study seems to represent a significant improvement in the reliability of knee muscle strength measurements. Coupled with the findings of Kozinc et al. [16], who reported moderate-to-high correlations (r = 0.64–0.80) between EasyForce and a rigid isometric dynamometer with external fixation, our results suggest that EasyForce is a valid and reliable instrument for assessing knee strength.

Our results also indicate that the direction of inter-limb asymmetry in knee extension demonstrated excellent consistency (κ = 0.90), indicating almost perfect agreement, whereas the agreement was substantial for knee flexion (κ = 0.71). At the same time, the ICC for the asymmetry data was 0.90 for both movements. This is a particularly important finding, considering that previous studies generally report suboptimal reliability of inter-limb asymmetry scores and poor agreement among different strength and power tests [9,19,20,31]. For example, the study by Bishop et al. [20] showed significant variation in the direction of inter-limb asymmetry across different physical performance tests, such as the unilateral isometric squat, countermovement jump, and broad jump. The kappa values ranged from –0.34 to 0.32, indicating poor-to-fair agreement, which suggests lower reliability and considerable variation in the direction of inter-limb asymmetry between tests. Similarly, Bishop et al. [32] found that in adolescent female soccer players, inter-limb asymmetry in three unilateral jump tests (single-leg countermovement jump, drop jump, and squat jump) rarely favored the same limb, with kappa values ranging from 0.02 to 0.45. One of the reasons could be that many of those tests are single-leg jump tests, where there are multiple strategies that can be achieved prior to take-off, which in turn, changes the subsequent data provided. Also, those tests are closed chain, which promotes much greater variability in movement [22]. The high kappa value in our study highlights the dynamometer's reliability in measuring inter-limb asymmetry. These findings are crucial for both clinical assessments and research, ensuring accurate detection of inter-limb asymmetry. This suggests that the EasyForce dynamometer could be a reliable option for detecting inter-limb asymmetry in knee strength and might be a preferable choice for such assessments.

Our study also demonstrated good-to-excellent reliability of HQ ratio assessment. The HQ ratio has been thoroughly studied, with a recommended value typically set at 0.65 for athletes [33]. A higher HQ ratio indicates that the hamstrings have a greater functional capacity to stabilize the knee, potentially reducing both anterior translation and anterolateral subluxation [34]. HQ ratios calculated using peak torque are valuable for detecting knee strength imbalances and assessing injury risk [35]. High ICC values (0.92 and 0.91 for the right and left sides, respectively), combined with low TE and moderate CV values (5.65–6.90%), indicate reliable and consistent HQ ratio measurements with EasyForce. The reliability of HQ assessment observed in our study was notably superior compared to that of Miralles-Iborra et al. [36], who combined a rigid chair, strain gauge sensor, and belt stabilization (ICC = 0.76–0.86; CV = 11.8–14.8%). Future studies may wish to consider how participant positioning impacts the reliability of the HQ ratio. For instance, a recent study by Baron et al. [37] reported that the reliability of HHD assessment of knee flexion force is impacted by knee joint position, with lower reliability in an extended knee position. In addition, our sample consisted of non-athletes who showed relatively low HQ ratios (mean: 0.43–0.44); therefore, further research is needed to ascertain the reliability of HQ assessment with EasyForce in athletes.

Study Limitations

This study has several limitations, including a small sample size of only 21 healthy volunteers, which may limit the generalizability of the findings to broader populations or individuals with different health conditions. The controlled, standardized testing environment might not accurately reflect real-world settings, although finding somewhere to fix such a device should be feasible in most working environments. The study focused solely on knee extension and flexion, which may not cover the full spectrum of muscle strength assessments needed in various scenarios. Future research should explore whether this device can be used more broadly and effectively for ongoing monitoring of quadriceps and hamstring strength, as these factors are considered potential risk factors for injuries.

5. Conclusions

The EasyForce dynamometer demonstrated good-to-excellent relative and absolute reliability for measuring knee extension and flexion, both within a single visit and across multiple visits. The study highlights the importance of device stabilization in enhancing measurement accuracy, as evidenced by lower coefficients of variation compared to previous studies. The set-up used in this study represents a notable improvement compared with previous studies using HHDs, particularly in terms of assessing inter-limb asymmetries and HQ ratios. To further establish the EasyForce dynamometer's utility, future research should consider its application in varied clinical and athletic environments, also examining factors such as user accessibility and performance consistency across different populations and settings.

Author Contributions: Conceptualization, N.N., S.J. and Ž.K.; methodology, N.N., S.J. and Ž.K.; software, D.V.; validation, N.N., S.J., D.V. and C.B.; formal analysis, Ž.K.; investigation, N.N., S.J. and Ž.K.; resources, D.V.; data curation, D.V. and Ž.K.; writing—original draft preparation, N.N., S.J. and Ž.K.; writing—review and editing, C.B. and Ž.K.; visualization, Ž.K.; supervision, Ž.K.; project administration, N.N.; funding acquisition, Ž.K. All authors have read and agreed to the published version of the manuscript.

Funding: The study was supported by the Slovenian Research Agency through the research program KINSPO—Kinesiology for the effectiveness and prevention of musculoskeletal injuries in sports (P5-0443).

Institutional Review Board Statement: This study was conducted according to the ethical principles stated in the Declaration of Helsinki and approved by the Ethics board of Academy of Applied Studies Belgrade (no. 01-264/4 from 22 May 2024).

Informed Consent Statement: Prospective participants were familiarized with the planned measurement procedures and signed an informed consent form.

Data Availability Statement: All collected data are included in the manuscript. Raw data are available immediately from the corresponding author upon reasonable request.

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

References

1. McMaster, D.T.; Gill, N.; Cronin, J.; McGuigan, M. A Brief Review of Strength and Ballistic Assessment Methodologies in Sport. *Sports Med.* **2014**, *44*, 603–623. [CrossRef] [PubMed]
2. Vanpee, G.; Hermans, G.; Segers, J.; Gosselink, R. Assessment of Limb Muscle Strength in Critically Ill Patients: A Systematic Review. *Crit. Care Med.* **2014**, *42*, 701–711. [CrossRef] [PubMed]
3. de la Motte, S.J.; Gribbin, T.C.; Lisman, P.; Murphy, K.; Deuster, P.A. Systematic Review of the Association Between Physical Fitness and Musculoskeletal Injury Risk: Part 2—Muscular Endurance and Muscular Strength. *J. Strength Cond. Res.* **2017**, *31*, 3218–3234. [CrossRef]
4. Hirschmann, M.T.; Müller, W. Complex Function of the Knee Joint: The Current Understanding of the Knee. *Knee Surg. Sports Traumatol. Arthrosc.* **2015**, *23*, 2780–2788. [CrossRef]
5. Murray, A.M.; Thomas, A.C.; Armstrong, C.W.; Pietrosimone, B.G.; Tevald, M.A. The Associations between Quadriceps Muscle Strength, Power, and Knee Joint Mechanics in Knee Osteoarthritis: A Cross-Sectional Study. *Clin. Biomech.* **2015**, *30*, 1140–1145. [CrossRef] [PubMed]
6. Xu, D.; Zhou, H.; Quan, W.; Gusztav, F.; Wang, M.; Baker, J.S.; Gu, Y. Accurately and Effectively Predict the ACL Force: Utilizing Biomechanical Landing Pattern before and after-Fatigue. *Comput. Methods Programs Biomed.* **2023**, *241*, 107761. [CrossRef] [PubMed]
7. Xu, D.; Lu, J.; Baker, J.S.; Fekete, G.; Gu, Y. Temporal Kinematic and Kinetics Differences throughout Different Landing Ways Following Volleyball Spike Shots. *Proc. Inst. Mech. Eng. Part P J. Sports Eng. Technol.* **2022**, *236*, 200–208. [CrossRef]
8. Parkinson, A.O.; Apps, C.L.; Morris, J.G.; Barnett, C.T.; Lewis, M.G.C. The Calculation, Thresholds and Reporting of Inter-Limb Strength Asymmetry: A Systematic Review. *J. Sports Sci. Med.* **2021**, *20*, 594–617. [CrossRef]

9. Bishop, C.; De Keijzer, K.L.; Turner, A.N.; Beato, M. Measuring Interlimb Asymmetry for Strength and Power: A Brief Review of Assessment Methods, Data Analysis, Current Evidence, and Practical Recommendations. *J. Strength Cond. Res.* **2023**, *37*, 745–750. [CrossRef]
10. Afonso, J.; Peña, J.; Sá, M.; Virgile, A.; García-de-Alcaraz, A.; Bishop, C. Why Sports Should Embrace Bilateral Asymmetry: A Narrative Review. *Symmetry* **2022**, *14*, 1993. [CrossRef]
11. Hirano, M.; Katoh, M.; Gomi, M.; Arai, S. Validity and Reliability of Isometric Knee Extension Muscle Strength Measurements Using a Belt-Stabilized Hand-Held Dynamometer: A Comparison with the Measurement Using an Isokinetic Dynamometer in a Sitting Posture. *J. Phys. Ther. Sci.* **2020**, *32*, 120–124. [CrossRef] [PubMed]
12. Lesnak, J.; Anderson, D.; Farmer, B.; Katsavelis, D.; Grindstaff, T.L. Validity of Hand-Held Dynamometry in Measuring Quadriceps Strength and Rate of Torque Development. *Int. J. Sports Phys. Ther.* **2019**, *14*, 180–187. [CrossRef]
13. Stark, T.; Walker, B.; Phillips, J.K.; Fejer, R.; Beck, R. Hand-Held Dynamometry Correlation with the Gold Standard Isokinetic Dynamometry: A Systematic Review. *PM R* **2011**, *3*, 472–479. [CrossRef]
14. Martins, J.; Da Silva, J.R.; Da Silva, M.R.B.; Bevilaqua-Grossi, D. Reliability and Validity of the Belt-Stabilized Handheld Dynamometer in Hip-and Knee-Strength Tests. *J. Athl. Train.* **2017**, *52*, 809–819. [CrossRef] [PubMed]
15. Bohannon, R.W.; Pritchard, R.O.; Glenney, S.S. Portable Belt-Stabilized Hand-Held Dynamometry Set-up for Measuring Knee Extension Force. *Isokinet. Exerc. Sci.* **2013**, *21*, 325–329. [CrossRef]
16. Kozinc, Ž.; Smajla, D.; Trajković, N.; Šarabon, N. Reliability of EasyForce Dynamometer for Assessment of Maximal Knee and Hip Strength, and Comparison to Rigid Isometric Dynamometers with External Fixation. *Meas. Phys. Educ. Exerc. Sci.* **2022**, *26*, 232–244. [CrossRef]
17. Trajković, N.; Kozinc, Ž.; Smajla, D.; Šarabon, N. Interrater and Intrarater Reliability of the EasyForce Dynamometer for Assessment of Maximal Shoulder, Knee and Hip Strength. *Diagnostics* **2022**, *12*, 442. [CrossRef] [PubMed]
18. Bohannon, R.W.; Kindig, J.; Sabo, G.; Duni, A.E.; Cram, P. Isometric Knee Extension Force Measured Using a Handheld Dynamometer with and without Belt-Stabilization. *Physiother. Theory Pract.* **2012**, *28*, 562–568. [CrossRef]
19. Cuthbert, M.; Comfort, P.; Ripley, N.; McMahon, J.J.; Evans, M.; Bishop, C. Unilateral vs. Bilateral Hamstring Strength Assessments: Comparing Reliability and Inter-Limb Asymmetries in Female Soccer Players. *J. Sports Sci.* **2021**, *39*, 1481–1488. [CrossRef]
20. Bishop, C.; Lake, J.; Loturco, I.; Papadopoulos, K.; Turner, A.; Read, P. Interlimb Asymmetries: The Need for an Individual Approach to Data Analysis. *J. Strength Cond. Res.* **2021**, *35*, 695–701. [CrossRef]
21. Bishop, C.; Coratella, G.; Beato, M. Intra-and Inter-Limb Strength Asymmetry in Soccer: A Comparison of Professional and under-18 Players. *Sports* **2021**, *9*, 129. [CrossRef] [PubMed]
22. Sarabon, N.; Kozinc, Z.; Bishop, C.; Maffiuletti, N.A. Factors Influencing Bilateral Deficit and Inter-Limb Asymmetry of Maximal and Explosive Strength: Motor Task, Outcome Measure and Muscle Group. *Eur. J. Appl. Physiol.* **2020**, *120*, 1681–1688. [CrossRef] [PubMed]
23. Hohmann, E.; Tetsworth, K.; Glatt, V. The Hamstring/Quadriceps Ratio Is an Indicator of Function in ACL-Deficient, but Not in ACL-Reconstructed Knees. *Arch. Orthop. Trauma Surg.* **2019**, *139*, 91–98. [CrossRef] [PubMed]
24. Bishop, C.; Turner, A.; Gonzalo-Skok, O.; Read, P. Inter-Limb Asymmetry During Rehabilitation: Understanding Formulas and Monitoring the "Magnitude" and "Direction". *Aspetar Sports Med. J.* **2020**, *9*, 18–22.
25. Helme, M.; Tee, J.; Emmonds, S.; Low, C. Does Lower-Limb Asymmetry Increase Injury Risk in Sport? A Systematic Review. *Phys. Ther. Sport* **2021**, *49*, 204–213. [CrossRef] [PubMed]
26. Donner, A.; Eliasziw, M. Sample Size Requirements for Reliability Studies. *Stat. Med.* **1987**, *6*, 441–448. [CrossRef]
27. Koo, T.K.; Li, M.Y. A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *J. Chiropr. Med.* **2016**, *15*, 155–163. [CrossRef]
28. Banyard, H.G.; Nosaka, K.; Haff, G.G. Reliability and Validity of the Load-Velocity Relationship to Predict the 1RM Back Squat. *J. Strength Cond. Res.* **2017**, *31*, 1897–1904. [CrossRef]
29. Chmura Kraemer, H.; Periyakoil, V.S.; Noda, A. Kappa Coefficients in Medical Research. *Stat. Med.* **2002**, *21*, 2109–2129. [CrossRef]
30. Lu, T.W.; Hsu, H.C.; Chang, L.Y.; Chen, H.L. Enhancing the Examiner's Resisting Force Improves the Reliability of Manual Muscle Strength Measurements: Comparison of a New Device with Hand-Held Dynamometry. *J. Rehabil. Med.* **2007**, *39*, 679–684. [CrossRef]
31. Davey, K.; Read, P.; Coyne, J.; Jarvis, P.; Turner, A.; Brazier, J.; Šarabon, N.; Jordan, M.J.; Bishop, C. An Assessment of the Hopping Strategy and Inter-Limb Asymmetry during the Triple Hop Test: A Test–Retest Pilot Study. *Symmetry* **2021**, *13*, 1890. [CrossRef]
32. Bishop, C.; Pereira, L.A.; Reis, V.P.; Read, P.; Turner, A.N.; Loturco, I. Comparing the Magnitude and Direction of Asymmetry during the Squat, Countermovement and Drop Jump Tests in Elite Youth Female Soccer Players. *Sci. Footb.* **2023**, *38*, 100–107. [CrossRef]
33. Aagaard, P.; Simonsen, E.B.; Magnusson, S.P.; Larsson, B.; Dyhre-Poulsen, P. A New Concept for Isokinetic Hamstring: Quadriceps Muscle Strength Ratio. *Am. J. Sports Med.* **1998**, *26*, 231–237. [CrossRef] [PubMed]
34. Hiemstra, L.A.; Webber, S.; MacDonald, P.B.; Kriellaars, D.J. Hamstring and Quadriceps Strength Balance in Normal and Hamstring Anterior Cruciate Ligament-Reconstructed Subjects. *Clin. J. Sport Med.* **2004**, *14*, 274–280. [CrossRef] [PubMed]
35. Ruas, C.V.; Pinto, R.S.; Haff, G.G.; Lima, C.D.; Pinto, M.D.; Brown, L.E. Alternative Methods of Determining Hamstrings-to-Quadriceps Ratios: A Comprehensive Review. *Sport. Med.—Open* **2019**, *5*, 11. [CrossRef]

36. Miralles-Iborra, A.; Moreno-Pérez, V.; Del Coso, J.; Courel-Ibáñez, J.; Elvira, J.L.L. Reliability of a Field-Based Test for Hamstrings and Quadriceps Strength Assessment in Football Players. *Appl. Sci.* **2023**, *13*, 4918. [CrossRef]
37. Baron, M.; Divernois, G.; Grandjean, B.; Guex, K. Validity and Reliability of Handheld Dynamometry to Assess Isometric Hamstrings and Quadriceps Strength at Varying Muscle Lengths. *J. Sport Rehabil.* **2024**, *33*, 267–274. [CrossRef]