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Research article

CAN INTER-LIMB ASYMMETRIES IN MUSCLE STRENGTH BE RELIABLY ASSESSED? A PRELIMINARY STUDY ON TEST-RETEST RELIABILITY AND THE EFFECT OF TESTING POSITION ON GRIP STRENGTH MEASUREMENTS

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Abstract. *This preliminary study investigates the test-retest reliability of assessing inter-limb asymmetries using grip strength measurements and examines the effect of testing positions (sitting vs. standing) on these assessments. The study involved ten healthy adults who participated in two testing sessions, where grip strength was measured using a Jamar dynamometer in both sitting and standing positions. The reliability of these measurements was analyzed using intraclass correlation coefficients (ICC) and other statistical measures, such as the typical error (TE) and coefficient of variation (CV). The results demonstrated good to excellent reliability for grip strength measurements in both sitting and standing positions, with ICC values ranging from 0.96 to 0.98. However, the reliability of asymmetry assessments showed greater variability, particularly in the sitting position, where the ICC for asymmetry was lower (0.82) compared to the standing position (0.91). The observed differences in reliability suggest that factors such as body posture, joint angles, and hand-grip positioning might significantly influence the outcomes of inter-limb asymmetry assessments. Moreover, the study found that asymmetry measurements varied between sessions, particularly in the sitting position, indicating potential learning effects or motivational differences. These findings underscore the importance of standardized testing protocols and suggest that a single testing procedure may not be sufficient to reliably assess inter-limb*

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asymmetries. Further research with larger sample sizes and more controlled conditions is recommended to validate these preliminary findings and to explore the influence of different testing positions on the reliability of asymmetry assessments.

Key words: *Inter-limb asymmetry, grip strength, test-retest reliability, testing position, handgrip dynamometer.*

INTRODUCTION

The assessment of performance in sports is essential for the development and progress of athletes (Bompa & Haff, 2009; Turner & Comfort, 2017). In various sports, training is often focused on increasing and maintaining muscular strength and power (Israetel, Hoffmann & Smith, 2015). Focusing on the development of strength, power, and capacity enables coaches and athletes to monitor progress accurately, identify weaknesses, and adjust training to achieve optimal results (Bompa & Haff, 2009). This involves using various methods and tools to measure maximal force, explosive power, endurance, and other specific tests tailored for individual sports (Bompa & Haff, 2009; Turner & Comfort, 2017).

Inter-limb asymmetries (the ratio between the performance of one limb compared to another) are also a critical parameter to consider when evaluating athletes (Blagrove, Bishop, Howatson & Hayes, 2021). These imbalances and asymmetries can significantly impact sports performance and are strongly associated with an increased risk of injuries (Bishop, Turner & Read, 2018; Knapik, Bauman, Jones, Harris & Vaughan, 1991). Research indicates that uneven distribution of strength and power between body sides can lead to excessive strain on specific joints and muscles, raising the likelihood of injuries such as muscle strains, ligament damage, and chronic overuse injuries (Helme, 2021). Although asymmetry is typically evaluated within the context of a sport-specific skill, tests assessing both bilateral and unilateral strength have been employed to measure inter-limb asymmetry and its impact on performance-related outcomes. Research (Bailey, Sato & Mcinnis, 2021) has shown that greater bilateral force asymmetry is linked to reduced jumping performance, while, interestingly, stronger athletes generally exhibit less strength asymmetry compared to weaker ones. Identifying and addressing asymmetries in strength and power is crucial for optimizing athlete preparation. Regular assessments enable coaches to tailor training programs and implement exercises to reduce asymmetries, enhancing performance and reducing injury risk (Baechle & Earle, 2008; Read, Lloyd, De Ste Croix & Oliver, 2013).

Tests such as isokinetic dynamometry, hand-held dynamometry (HHD), 1-repetition maximum (RM), and maximal power tests are frequently cited in the literature as assessment methods (Paul & Nassis, 2015). In sports diagnostics, isokinetic dynamometers are commonly used to evaluate strength. Despite their utility, they are costly and typically assess only one joint at a time (Yen, 2005). They are considered essential for assessing muscle function and imbalances in clinical, research, and sports settings (Paul & Nassis, 2015). Research has explored the relationship between isokinetic strength indices and functional performance measures like sprinting, repeated sprint ability, and the vertical jump, but the low to moderate shared variance suggests these tests are largely independent due to differing movements (Paul & Nassis, 2015).

Reliability is a fundamental aspect of interpreting clinical trial results, as it assesses changes and score variability across repeated test occasions (Bartlett & Frost, 2008). Ensuring high reliability for both limbs is crucial, as discrepancies—such as one limb having 'good' reliability and the other 'poor'—can result in flawed data analysis and unreliable between-limb comparisons (Clark, Reilly & Davies, 2019).

Although strength tests show high repeatability, interpreting asymmetries requires caution. Studies have shown 27-34% of basketball and volleyball players exhibit over 15% asymmetry in vertical jump height (Fort-Vanmeerhaeghe, Gual, Romero-Rodriguez & Unnitha, 2016). Inter-limb asymmetries in knee extensor strength vary with contraction velocity, being higher at 60°/s compared to 180°/s (Schons et al., 2019; Cheung et al., 2012), while leg press task asymmetries are very low (Mattes, Wollesen & Manzer, 2018). The discrepancy in these findings suggests that a single testing procedure may not be sufficient to detect all aspects of strength imbalances between limbs (Kozinc & Šarabon, 2020). It is also crucial to remember that strength and power characteristics represent only one facet of performance and should be considered as part of a multidisciplinary approach; thus, testing should reflect this perspective (Paul & Nassis, 2015). Previous research has highlighted the importance of displaying individual participant inter-limb asymmetry data due to the large intra-individual variation that can potentially exist between side dominance and tests (Bishop, Read, McCubbine & et al., 2021). Recent studies on whether asymmetries impact sports performance have yielded inconclusive results (Bishop et al., 2018). Hart et al. (2014) found that 8% strength asymmetries reduced kicking accuracy, whereas Dos'Santos et al. (2017) found no association between strength or hop asymmetries (around 7-13%) and CODS performance. In contrast, Bishop et al. (2018) reported that vertical and horizontal asymmetries were linked to reduced jump and sprint performance in elite youth female soccer players. This lack of consensus indicates the need for further research.

Most literature relating asymmetries to physical performance measures has used jump tests to quantify the asymmetry component (Bishop et al., 2021; Dos'Santos et al., 2017; Hoffman et al., 2007; Lockie et al., 2014; Maloney, Richards, Nixon, Harvey & Fletcher, 2017). Inter-limb differences from horizontal jumping (such as single, triple, and crossover hop tests) have reported mean asymmetries of 6–7% (Bishop et al., 2021; Dos'Santos et al., 2017; Meylan et al., 2009). When vertical asymmetries have been assessed through a single-leg countermovement jump (SLCMJ), these differences have been shown to be significantly greater than horizontal tests, with values greater than 10% being common for this test.

Given the significant role that strength asymmetries can play in athletic performance and injury prevention, we aimed to investigate whether such asymmetries could be reliably measured using a simple test such as handgrip strength. Our aim was to determine if the grip test could provide accurate and reliable data on inter-limb asymmetries.

METHODS

Participants

The study involved a sample of 10 healthy adults (4 men and 6 women) aged between 18 and 22 years. Participants were recruited from the local university and surrounding community through advertisements. Inclusion criteria required participants to be free from any upper limb musculoskeletal injuries or neurological conditions that could affect grip strength. Additionally, the participants were required to be right-handed as determined by a self-report questionnaire to minimize the variability in handedness that might affect grip strength asymmetry. Prior to participation, all of the participants provided written informed consent. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Commission of the University of Primorska for Ethics in Human Subjects Research (approval number: 4264-19-6/23).

Study design and measurements

This study employed a repeated-measures design to assess the test-retest reliability of grip strength measurements and the influence of testing position on inter-limb asymmetries. The participants were tested on two separate occasions, with a minimum of 4 days and a maximum of 7 days between sessions to mitigate potential carryover effects and allow for adequate recovery. Grip strength was measured using a calibrated Jamar handgrip dynamometer (Sammons Preston, Bolingbrook, IL, USA), which is widely recognized for its validity and reliability in strength assessments (Allen & Barnett, 2011). Measurements were taken in two positions: sitting and standing. In the sitting position, the participants were seated with their elbow flexed at 90 degrees, forearm in a neutral position, and wrist in slight extension. In the standing position, the participants stood upright with their arms hanging naturally by their sides and the dynamometer positioned in the same manner as in the sitting position. The handle of the dynamometer was accommodated to each participant and was kept consistent throughout the measurements.

The participants performed three maximal grip strength trials with each hand in both positions during each session. The order of testing (sitting or standing) was randomized to control for potential order effects. A 60-second rest interval was provided between trials to prevent muscle fatigue. A 60-second rest interval was selected based on evidence suggesting it is sufficient for neuromuscular recovery during submaximal efforts while maintaining testing efficiency (de Salles et al., 2009). The highest value obtained from the three trials was recorded as the maximum grip strength for that hand in each position. Inter-limb asymmetry was calculated as the percentage difference between the dominant and non-dominant hand grip strength. All measurements were conducted by the same examiner, who was blinded to the study’s hypothesis, to ensure consistency in the testing procedures.

Data analysis and statistics

The data are presented as means ± standard deviations. The reliability across repetitions was evaluated with intra-class correlation coefficient (ICC; single measures, absolute agreement). We considered ICC values <0.5 to be indicative of poor reliability, values between 0.5 and 0.75 to indicate moderate reliability, values between 0.75 and 0.9 to indicate good reliability, and values greater than 0.90 to indicate excellent reliability (Koo & Li, 2016). Additionally, absolute reliability was assessed by calculating the typical error (TE) and coefficient of variation (CV), which was interpreted as poor (CV > 10%), moderate (CV = 5–10%) and good (CV < 5%) (Banyard, Nosaka, Vernon & Haff, 2018). Kappa coefficients were calculated to determine the levels of agreement for the direction of asymmetries between the sessions and between the testing conditions. The agreement was interpreted as follows 0.01–0.20 = slight; 0.21–0.40 = fair; 0.41–0.60 = moderate; 0.61–0.80 = substantial; 0.81–0.99 = nearly perfect. Differences between testing conditions were assessed with a paired-sample t-test. All analyses were carried out using SPSS statistical software (version 25.0, IBM: Armonk, NY, USA).

RESULTS

The reliability of assessing inter-limb asymmetries through grip strength tests was evaluated in sitting and standing positions (Table 1). In the sitting position, the right limb showed good to excellent relative reliability with an ICC of 0.96 (95% CI: 0.84-0.99), TE of 3.13 N, and CV of 7.53%. The left limb demonstrated excellent reliability with an ICC of 0.98 (95% CI: 0.93-1.00), TE of 2.07 N, and CV of 4.88%. Asymmetry percentages, although exhibiting ICC with point-estimate indicated moderate reliability (ICC = 0.82, 95% CI: 0.43-0.95) with a TE of 3.53%, but the confidence intervals spanned from poor to excellent reliability.

In the standing position, the right limb had an ICC of 0.97 (95% CI: 0.89-0.99), TE of 2.83 N, and CV of 6.56%, indicating good to excellent reliability. The left limb showed similar results with an ICC of 0.98 (95% CI: 0.92-0.99), TE of 2.22 N, and CV of 5.22%, indicating excellent reliability. Asymmetry percentages in this position showed high reliability (ICC = 0.91, 95% CI: 0.69-0.98) with a TE of 3.12%, but the confidence intervals spanned from moderate to excellent reliability.

The pair-sample t-test indicated that there were no statistically significant differences between the sessions in the right ($p = 0.645 – 0.918$) and left side ($p = 0.195 – 0.296$) force values. The asymmetry in the sitting position was different between the sessions ($p = 0.035$; Session 1: $–4.23 \pm 7.13$ %; Session 2: $–0.44 \pm 7.81$ %), but this was not the case for the standing position ($p = 0.095$). Regarding the direction of the asymmetry, the Kappa coefficients indicated a fair but agreement between sessions for sitting position ($\kappa = 0,4$) and moderate agreement in the standing position ($\kappa = 0.61$). Figure 1 shows participant-by-participant scores between session in sitting (upper chart) and standing (lower chart) positions. The agreement between sitting and standing positions was moderate at both the first ($\kappa = 0.54$) and substantial during the second session ($\kappa = 0.8$).

DISCUSSION

Considering the critical impact that strength asymmetries can have on athletic performance and injury prevention, this study set out to explore whether such asymmetries can be reliably measured using a straightforward test like handgrip strength. The reliability of assessing inter-limb asymmetries through grip strength tests was evaluated in sitting and standing positions (Table 1). In the sitting position, the right limb showed good to excellent relative reliability with an ICC of 0.96 (95% CI: 0.84-0.99), the left limb demonstrated excellent reliability with an ICC of 0.98 (95% CI: 0.93-1.00). Meanwhile, in the standing position, the right limb had an ICC of 0.97 (95% CI: 0.89-0.99), indicating good to excellent reliability, the left limb showed similar results with an ICC of 0.98 (95% CI: 0.92-0.99), indicating excellent reliability. Asymmetry percentages for sitting and standing position indicated moderate to high reliability but the confidence intervals spanned from poor to excellent reliability.

Table 1 Test-retest reliability

Position	Outcome variable	Session 1		Session 2		Relative reliability			Absolute reliability					
		Mean	SD	Mean	SD	ICC	95% CI		TE	95% CI		CV	95% CI	
Sitting	Force – right limb (N)	41.20	11.77	41.87	14.31	0.96	0.84	0.99	3.13	2.15	5.71	7.53	5.18	13.75
	Force – left limb (N)	43.17	12.82	41.87	13.56	0.98	0.93	1.00	2.07	1.43	3.79	4.88	3.36	8.91
	Asymmetry (%)	-4.23	7.13	-0.44	7.81	0.82	0.43	0.95	3.53	2.43	6.44	/	/	/
Standing	Force – right limb (N)	43.07	13.30	43.20	15.09	0.97	0.89	0.99	2.83	1.95	5.16	6.56	4.51	11.97
	Force – left limb (N)	43.03	12.59	41.93	13.68	0.98	0.92	0.99	2.22	1.52	4.05	5.22	3.59	9.53
	Asymmetry (%)	-0.65	8.91	1.94	9.55	0.91	0.69	0.98	3.12	2.15	5.69	/	/	/

Legend: SD: Standard Deviation; ICC: Intraclass Correlation Coefficient; CI: Confidence Interval; TE: Typical Error; CV: Coefficient of Variation

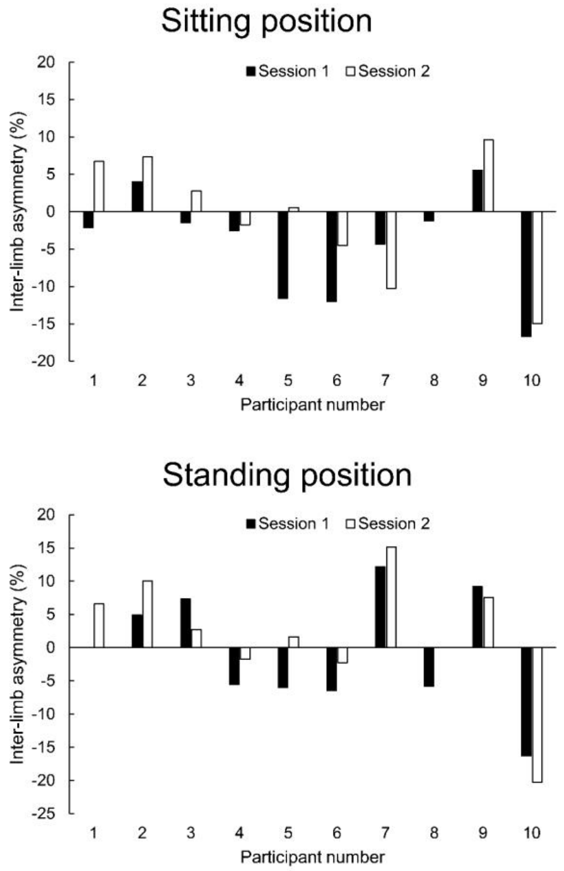

Fig. 1 Participant-by-participant asymmetry values between sessions.

HGS also showed a high reliability in other studies (Peolsson et al., 2001; Gąsior et al., 2020; Maurya, Sisneros, Johnson & Palmer, 2023) and is considered the gold standard to validate other isometric HGS instruments (Peolsson et al., 2001; Gąsior et al., 2020; Roberts et al., 2011; Shechtman et al., 2004). The asymmetry in the sitting position was different between the sessions ($p = 0.035$), but this was not the case for the standing position ($p = 0.095$). The obtained results were contrary to our expectations, as we anticipated no changes between sessions in the sitting position or expected changes only in the standing position. The reason for the different results between sessions when performing the test could be body posture and altered joint angles (Turnes, Silva, Kons & Detanico et al., 2022). Specifically, in the sitting position, with a bent elbow joint, the occurrence of movement compensations is minimized, while in the standing position, postural adjustments with synergistic action of the trunk and shoulder muscles are simultaneously required (Turnes et al., 2022), which could result in greater asymmetries between sessions, but this was not the case in our study. Also, giving table support to the flexed elbow in sitting position could lead to lesser compensations during measurement and therefore better reliability in asymmetry testing. One of the possible reasons for different outcomes between sessions could also be a hand-grip position. Boadella et al. (2005) showed that the participants who chose their optimal hand-grip position on the dynamometer had delivered maximal strength, which means that the participants in our study could use one hand-grip position in session 1 and the other hand-grip position in session 2. A possible learning effect and/or motivational factors can also explain the noticed difference in asymmetries in the sitting position in our study, which can be prevented by a larger number of practice trials or by a familiarization procedure (Gąsior et al., 2020). Also, findings represent on Figure 1 highlight the importance of standardizing posture in handgrip strength measurements, as the agreement between sitting and standing positions improved from moderate ($\kappa = 0.54$) in the first session to substantial ($\kappa = 0.8$) in the second session, indicating possible increased reliability with consistent protocols.

Despite the promising findings, several limitations of this study should be acknowledged. A limitation of the study is the small sample size, comprising only 10 healthy adults, which limits the generalizability of the findings. Additionally, the focus on handgrip strength measurements in this specific age group may not capture variations across different age ranges, fitness levels, or populations with diverse physical characteristics. Future studies should include a larger and more diverse population to provide more comprehensive and representative results.

Also, one key limitation is the potential variability in hand-grip positioning across sessions. As noted by Boadella et al. (2005), optimal hand-grip positioning can significantly impact the strength measurements. In our study, the participants may have unknowingly varied the hand-grip position as they accommodated to the dynamometer, possibly leading to variations in the recorded strength and asymmetry values. Another limitation is the possible influence of a learning effect or changes in motivational levels between sessions. The participants may have become more familiar with the test procedure or altered their effort levels, particularly in the sitting position, where significant differences in asymmetry between sessions were observed. Although steps were taken to standardize the testing environment, these factors could not be entirely controlled and may have affected the reliability of the results.

The differences in body posture and joint angles between the sitting and standing positions may have also contributed to the variability in asymmetry measurements. The study indicated that the sitting position, which minimizes movement compensations, still showed significant differences between sessions. This suggests that subtle variations in posture, even in a controlled position, can influence the outcomes, potentially limiting the generalizability of the findings. Although the grip strength test demonstrated good to excellent reliability in measuring inter-limb asymmetries, the confidence intervals for asymmetry percentages spanned from poor to excellent reliability. This variability suggests that even handgrip strength test is not sufficiently reliable for accurately assessing inter-limb asymmetries.

CONCLUSIONS

This study aimed to explore the reliability of using handgrip strength as a straightforward method for assessing inter-limb asymmetries, which are critical for athletic performance and injury prevention. The findings demonstrated that handgrip strength tests, particularly in both sitting and standing positions, generally provide good to excellent reliability in measuring these asymmetries. However, the study also revealed some unexpected variability, particularly in the sitting position, where differences between sessions were observed. These variations may be attributed to factors such as hand-grip positioning, learning effects, and differences in body posture, highlighting the need for more controlled conditions in future studies. Future research should examine the impact of grip positioning, learning effects, and body posture on handgrip strength reliability, while including larger and more diverse populations to further validate its use in assessing inter-limb asymmetries.

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DA LI SE ASIMETRIJE MIŠIĆNE SNAGE IZMEĐU UDOVA MOGU POUZDANO PROCENITI? PRELIMINARNA STUDIJA O TEST-RETEST POUZDANOSTI I UTICAJU POLOŽAJA TESTIRANJA NA MERENJA SNAGE HVATA

Ova preliminarna studija istražuje test-retest pouzdanost procene asimetrija između udova koristeći merenja snage hvata i ispituje uticaj položaja testiranja (sedenje naspram stajanja) na ove procene. U istraživanju je učestvovalo deset zdravih odraslih osoba, u dve sesije testiranja, gde je snaga hvata merena pomoću Jamar dinamometra u sedećem i stojećem položaju. Pouzdanost ovih merenja analizirana je pomoću intraklasnih koeficijenata korelacije (ICC) i drugih statističkih mera, kao što su tipična greška (TE) i koeficijent varijacije (CV). Rezultati su pokazali dobru do odličnu pouzdanost za merenja snage hvata u oba položaja, sa ICC vrednostima u rasponu od 0.96 do 0.98. Međutim, pouzdanost procene asimetrija pokazala je veću varijabilnost, posebno u sedećem položaju, gde je ICC za asimetriju bio niži (0.82) u poređenju sa stojećim položajem (0.91). Uočene razlike u pouzdanosti sugerišu da faktori poput telesnog položaja, uglova zglobova i pozicioniranja ruku mogu značajno uticati na rezultate procene asimetrija između udova. Pored toga, studija je otkrila da su se merenja asimetrija razlikovala između sesija, naročito u sedećem položaju, ukazujući na moguće efekte učenja ili razlike u motivaciji. Ovi nalazi naglašavaju važnost standardizovanih protokola testiranja i sugerišu da jedan postupak testiranja možda nije dovoljan *za pouzdanu procenu asimetrija između udova. Preporučuju se dalja istraživanja sa većim uzorcima i kontrolisanim uslovima kako bi se potvrdili ovi preliminarni nalazi i istražio uticaj različitih položaja testiranja na pouzdanost procene asimetrija.*

Ključne reči: *asimetrija između udova, snaga hvata, test-retest pouzdanost, položaj testiranja, dinamometar za ruku.*