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Reliability and concurrent validity of the bubble inclinometer for visual estimation of straight leg raise in asymptomatic individuals

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Abstract

Introduction. The straight leg raise (SLR) test is commonly used to investigate neurodynamic problems or hamstring muscle length. Visual estimation can be used to identify the degrees of hip flexion during the SLR test. However, intra-tester and inter-tester reliability, as well as concurrent validity, await formal investigation.

Methods. This study was an experimental study. Two testers, a novice and an experienced physical therapist, measured hip flexion angles during the SLR test using visual estimation for two sessions and the bubble inclinometer method during the first session in 31 asymptomatic participants, in random order. Intra-tester reliability (intraclass correlation coefficient, $ICC_{3,3}$), inter-tester reliability ($ICC_{2,3}$), concurrent validity (Pearson correlation with bubble inclinometer), and measurement error was represented as standard error of measurement (SEM) and minimal detectable change (MDC), were calculated.

Results. The concurrent validity and intra-tester reliability of visual estimation for both testers were good ($ICC_{3,3}$ = 0.885 with 95% confidence interval = 0.775–0.943, $p < 0.001$) and excellent ($ICC_{3,3}$ = 0.904 with 95% confidence interval = 0.810–0.952, $p < 0.001$), respectively. Inter-tester reliability of visual estimation was poor ($ICC_{2,3}$ = 0.373 with 95% confidence interval = 0.027–0.639, $p = 0.018$).

Conclusions. Although the concurrent validity of visual estimation with the bubble inclinometer was good, and intra-tester reliability was excellent, the inter-tester reliability was poor. Therefore, caution should be exercised if more than one tester is involved in visual estimation.

Key words: reliability, straight leg raise, visual estimation

Introduction

The straight leg raise (SLR) test is a passive neurodynamic test commonly used to investigate the mechanical movement of neurological tissues, particularly its sensitivity to mechanical stress or compression in patients with lumbar problems or lumbar-related radicular complaints [1]. This test is not only used to detect the sensitivity of neurological tissues but also to measure the length of the hamstring muscle group [2, 3]. The major movement in this test is hip flexion, with different angles of hip flexion suggesting various possible pathologies, such as disc herniation, sciatic nerve involvement, hip and sacroiliac problems, and tightness of the hamstring muscle [4].

The methods for the SLR test include the universal goniometer and the inclinometer [5]. However, the disadvantage of the universal goniometer is that the measurement process requires clinicians to identify anatomical landmarks while simultaneously placing the goniometer, making it more difficult to stabilize the patient's position. This could increase the risk of measurement error [6]. In contrast, the inclinometer is simpler for measuring hip flexion during the SLR test. It has been reported to have excellent intra-rater reliability in SLR tests [7–10], and its construct validity has been highly correlated with both the digital inclinometer and the digital goniometer [9].

In clinical practice, the hip flexion angle during the SLR test may be visually estimated by clinicians, and the estimated values are either verbally communicated or recorded for physical examination information. It has been previously reported that visual estimation of range of motion is more frequently used by physical therapists than measurement devices [11]. The inter-tester reliability of visual estimation for active dorsiflexion and plantarflexion range of motion has been investigated [11]. In addition, the agreement of visual estimation between therapists has been studied in cervical spine active range of motion [12] and knee passive range of motion [13]. However, the measurement of hip flexion angle during the SLR test by visual estimation has not been reported, even though this movement is simple and frequently used.

Reporting the degrees of hip flexion in the SLR test depends on the end of passive hip flexion, which is determined by patient complaints of pain or tightness in the back or posterior aspect of the leg [4]. Clinical experience may influence this decision. It is challenging to study how much variability in visual estimation could be detected between novice and experienced physical therapists. However, there is no information regarding the intra-tester, inter-tester reliability, and concurrent validity of visual estimation in the SLR test. The research questions in this study are how reliable the intra-tester and inter-tester estimates are and how comparable the results of visual estimation and the bubble inclinometer are in measuring the SLR. Therefore, the purposes of this study were to investigate the intra-tester and inter-tester reliability and the concurrent validity of visual estimation of hip flexion angles in SLR tests. We hypothesized that the intra-tester and inter-tester reliability would be acceptable and that visual estimation of hip flexion angles in SLR tests would be con-

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currently valid. The findings of this study will help researchers and clinicians determine whether the reliability and validity of visual estimation of the SLR test should be considered in clinical and experimental settings.

Subjects and methods

Examiners and participants

There were two measurement examiners, testers A and B, and a recording examiner. Tester A (SS), female, aged 41 years, had 18 years of clinical experience with patients having musculoskeletal conditions, while tester B (PK), female, aged 24, had less than 2 years of clinical experience. The recording examiner (TJ), with less than 2 years of clinical experience, silently read and recorded the bubble inclinometer test results and the visually estimated verbal results from testers A and B.

This study involved healthy young adults, both male and female. There were 31 participants with no known significant health problems: 20 women and 11 men, aged between 18 and 30 years. The exclusion criteria were musculoskeletal or neurological disorders and pain in the last 6 months, and vigorous physical activity within 24 h before participation. All eligible participants were informed about the procedure and possible risks and then signed an informed consent form.

The total sample size of 31 participants was pre-determined with the consideration that parametric statistics could be used because the sample size was large enough (more than 30 subjects) [14].

SLR measurement

For the starting position, participants, wearing comfortable clothes, lay supine on a plinth without a pillow, with both legs fully extended in a neutral position and the trunk aligned straight with no lateral flexion or rotation. Before measurements, the bubble inclinometer (Baseline®, Fabrication Enterprises; White Plains, New York) was placed on a flat, horizontally leveled surface and zeroed, then placed on the anterior surface of the tibia. The tester stood next to the participant's testing leg. The tester performed the SLR test by raising the participant's relaxed and straight leg to the maximum resistance or until the participant reported tightness in the back or posterior aspect of the thigh. The testers were blinded to the measurement values, with the front panel of the bubble inclinometer facing the recording examiner, who was opposite the testers. The recording examiner silently read the data from the front panel of the bubble inclinometer and obtained the verbal result from the tester's visual estimation and recorded the degrees of hip flexion [15].

Procedure

This study was an experimental study. Both testers learned the testing protocol and practiced for 2 h with a participant to become familiar with the process before the reliability study. The SLR was tested on the dominant leg, determined by drawing a figure of eight, kicking a ball, and picking up an object from the floor. The testers were randomized for testing order by sequences in a concealed envelope. Visual estimation during SLR tests was done for 2 sessions with 15 min apart, while the bubble inclinometer was used only during the first session. Each session of the SLR test was performed three times, with the average values used for analysis, and a rest period of at least 15 s was allowed between trials. Before each trial, participants confirmed with the testers that there was no discomfort or change in feelings in the back or leg. The testers were blinded to the measurement results read and recorded by another investigator.

Statistical analysis

This study used the SPSS program (IBM SPSS Statistics for Windows, version 23; Armonk, NY, USA) for statistical analysis, with a significance level set at $p < 0.05$. Descriptive data, including mean and standard deviation, were calculated for demographic data. The reliability of all measurements was determined by the intraclass correlation coefficient (ICC). A two-way mixed model ($ICC_{3,3}$) was used for intra-tester reliability, and a two-way random model ($ICC_{2,3}$) was used for inter-tester reliability. The ICCs indicated the relative reliability of tester measurements. Concurrent validity of visual estimation was anchor-based method. We assessed the concurrent validity of visual estimation anchored with the bubble inclinometer, the Pearson correlation (r) was used. The standard error of measurement (SEM) was calculated to represent absolute reliability according to tester measurements [16], with $SEM = SD\sqrt{(1–ICC)}$ or $SEM = SD\sqrt{(1–r)}$ [6]. The minimal detectable change (MDC), defined as the minimal amount of change needed to be greater than the within-subject variability and measurement error, was calculated as $MDC = SEM \times 1.96 \times \sqrt{2}$ [6]. The interpretation for ICC and r was as follows: < 0.5 poor reliability, 0.5–0.75 moderate, 0.75–0.9 good, and > 0.9 excellent. A paired t-test was used to compare the means between visual estimation and the bubble inclinometer for each tester.

Results

The average age, weight, height, and BMI of 31 participants were 23.86 years, 56.75 kg, 165.45 cm, and 20.69 kg/m^2, respectively (Table 1).

Table 1. Demographic data of the participants

Participants	Mean ± *SD*	Range
Age (years)	23.86 ± 2.92	19–30
Weight (kg)	56.75 ± 6.95	45.00–74.00
Height (cm)	165.45 ± 7.87	150.00–181.00
BMI (kg/m^2)	20.69 ± 1.59	17.70–23.90

The data in this study were normally distributed, as tested by the Kolmogorov–Smirnov Goodness of Fit test. The average values of visual estimation sessions 1 and 2 for tester A were 56.343 and 57.203, respectively, and for tester B were 63.803 and 65.201, respectively. The mean difference between testers A and B in visual estimation session 1 was 7.460 degrees (Table 2).

Intra-tester reliability of visual estimation for tester A was good, with $ICC_{3,3} = 0.885$ (95% confidence interval = 0.775–0.943, $p < 0.001$), SEM = 4.380, and MDC = 12.140 degrees. Tester B was excellent, with $ICC_{3,3} = 0.904$ (95% confidence interval = 0.810–0.952, $p < 0.001$), SEM = 3.454, and MDC = 9.573 degrees (Table 3).

Inter-tester reliability of visual estimation was poor, with $ICC_{2,3} = 0.373$ (95% confidence interval = 0.027–0.639, $p = 0.018$), SEM = 9.527, and MDC = 26.406 degrees (Table 4).

Concurrent validity of visual estimation was significantly correlated with bubble inclinometer methods, $r = 0.761$ ($p < 0.001$), SEM = 5.028, and MDC = 13.936 degrees (Table 5).

Table 2. Visual estimation and bubble inclinometer for testers A and B

Tester	Measurements (degrees)	Mean	*SD*	Mean difference (VE 1 – BI)	Mean difference [VE 1 (A) – VE 1 (B)]
A	VE 1	56.343	13.370	–2.438	–7.460
	VE 2	57.203	12.460		
	BI	58.781	6.165		
B	VE 1	63.803	11.558	1.387	
	VE 2	65.201	10.736		
	BI	62.416	10.045		

VE 1 – visual estimation session 1, VE 2 – visual estimation session 2, BI – bubble inclinometer

Table 3. Intra-tester reliability of visual estimation of testers A and B

Tester	$ICC_{3,3}$	95% CI	*p*-value	SEM	MDC
A	0.885	0.775, 0.943	< 0.001	4.380	12.140
B	0.904	0.810, 0.952	< 0.001	3.454	9.573

ICC – intraclass correlation coefficient, CI – confidence interval, SEM – standard error of measurement, MDC – minimal detectable change

Table 4. Inter-tester reliability of visual estimation from both testers

Tester	$ICC_{2,3}$	95% CI	*p*-value	SEM	MDC
A and B	0.373	0.027, 0.639	0.018	9.527	26.406

ICC – intraclass correlation coefficient, CI – confidence interval, SEM – standard error of measurement, MDC – minimal detectable change

Table 5. Concurrent validity of visual estimation and bubble inclinometer of testers A and B

Tester	Pearson *r*	95% CI	*p*-value	SEM	MDC
A	0.739	0.484, 0.995	< 0.001	4.990	13.832
B	0.817	0.597, 1.036	< 0.001	4.621	12.808

CI – confidence interval, SEM – standard error of measurement, MDC – minimal detectable change

Discussion

This study aimed to investigate the intra-tester and inter-tester reliability of visual estimation done by novice and experienced physical therapists, and its concurrent validity compared to bubble inclinometer methods in individuals without any symptoms. The end position of hip movement was stopped by the tightness at the posterior aspect of their thighs, and the testers then determined the hip flexion angles.

This study found that the intra-tester reliability for testers A and B was good to excellent. However, their MDCs were so high that the real change in SLR hip flexion angles after effective interventions must be greater than 12.140 or 9.573 degrees to be considered a valid change. Meanwhile, the MDC for intra-tester reliability of the digital inclinometer and digital goniometer in the SLR test was reported between 1.5 and 3.41 degrees only [17]. The inter-tester reliability of visual estimation between both testers in this study was poor, with an $ICC_{2,3}$ of 0.373 and an MDC of 26.406 degrees. The mean difference in visual estimation between testers A and B in the present study was 7.460 degrees. The poor inter-tester reliability results of this study corresponded to a previous study that reported the inter-tester reliability of visual estimation for active ankle dorsiflexion and plantarflexion range of motion as poor, with $ICC_{1,1}$ of 0.34 and 0.48, respectively [11].

The concurrent validity of visual estimation compared to the bubble inclinometer for testers A and B in this study was good. This indicated that visual estimation was consistent with the bubble inclinometer methods. However, their MDCs for visual estimation and bubble inclinometer methods ranged between 12.808 and 13.936 degrees, which necessitates caution if a valid change is needed. In addition, previous studies found less agreement between therapists in visual estimation of cervical spine active range of motion [12] and knee passive range of motion [13] compared to universal goniometer methods.

This study found that visual estimation from both intra-tester and inter-tester analyses was not reliable, as represented by SEM and MDC. It has been previously found and reported that clinicians often under- or overestimate joint angles [18]. Therefore, this study does not recommend visual estimation for assessing SLR hip flexion angles due to its significant variability, especially between clinicians, which may mislead the management and interpretation of physical examinations.

The visual estimation of the SLR test may be used by the same tester because the results showed good and excellent intra-tester reliability with good concurrent validity of visual estimation and bubble inclinometer. However, visual estimation may not be appropriate for comparison between testers.

Limitations

The limitations of this study include that the participants had no symptoms in their back or legs. Therefore, the results are limited in generalizability to populations with low back pain or leg pain, where the termination of the test might affect hip flexion angles. In addition, because the participants had no neurodynamic problems, the combination of foot movements during the SLR test for neural sensitization was not assessed, which might lead to different estimations of hip flexion angles in those with combined foot movements because multi-dimensional positions can be involved. However, this study focused on hip flexion angles because they are common in the SLR test and are often discussed among clinicians [4].

Conclusions

This study found good and excellent intra-tester reliability for visual estimation but poor inter-tester reliability. The concurrent validity of visual estimation compared to the bubble inclinometer was good, with a significant correlation. However, subject variability and measurement errors in visual estimation, as represented by MDC, were very high. Therefore, visual estimation can be used by the same tester; however, caution should be exercised if more than one tester is involved in measuring SLR in the same patient.

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Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Mahidol University Central Institutional Review Board (approval No.: MU-CIRB 2018/063.2003).

Informed consent

Informed consent has been obtained from all individuals included in this study.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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