ORIGINAL PAPER

Physiotherapy Quarterly (ISSN 2544-4395)
2024, 32(1), 73–77

Test–retest and inter-rater reliability of lumbar range of motion procedure using back range of motion instrument

DOI: https://doi.org/10.5114/pq.2024.135426

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Abstract

Introduction. To investigate the test–retest and inter-rater reliability of a new protocol using the back range of motion instrument (BROM II) to measure the lumbar range of motion (LROM).

Methods. Five raters and twenty healthy subjects participated in this study. Before the measurement, all raters and all subjects were asked to watch a 4-minute video clip demonstrating the rating method. The raters and the subjects were then asked to practice the testing protocol until they thoroughly understood it. The subjects were asked to move the lumbar spine in six directions, with consistent verbal instruction. The raters measured the subjects' LROM twice and were blinded to the data. The intra-class correlation coefficients were used to estimate the test–retest and inter-rater reliability of the LROM.

Results. The results showed that the intra-rater reliability [ICC(3,1)] was good-to-excellent, ranging from 0.82 to 0.98, except for the LROM in the right rotation, which was moderate-to-good, ranging from 0.74 to 0.97. The inter-rater reliability [ICC(2,1)] was good-to-excellent, ranging from 0.78 to 0.87.

Conclusion. The intra- and inter-rater reliability of this protocol in measuring LROM obtained by the BROM II were reliable and suitable for both teaching and research.

Key words: range of movement, BROM II, reliability, lumbar spine, low back pain

Introduction

Physical therapists commonly assess pain and range of movement changes to note the effectiveness of physical therapy interventions. Lumbar range of motion (LROM) is one of the most-used outcome measures in clinics in managing low back pain. Previous studies showed several methods used to assess the LROM, including tape measurement [1–3], finger-tip-to-floor method [1], flexible ruler [4, 5], universal goniometer [6–8], inclinometer [7, 9, 10], and back range of motion instrument (BROM II) [7, 10].

The BROM II was developed using a similar principle to the goniometer and inclinometer methods [11–12]. The criterion-related validity of the BROM II has also been investigated using an inclinometer. The BROM II was validated and documented ($r = 0.78$) [13]. In addition, previous studies investigated the inter-rater and test–retest reliability of the BROM II when used to measure LROM [7, 10, 12, 14]. The reliability correlation coefficients in these studies were reported from 0.35 to 0.95, which is a wide range. It is possible that the protocols tested in each study did not follow a standardised method. The researchers and subjects recruited may have performed the tested protocol in different ways. Thus, there is a need to develop a protocol to reliably measure LROM.

Video clips have been shown to help test subjects make significant progress in mastering skills [15]. A 4-minute instructional video that demonstrated the measurement of LROM was created. The video clip showed how LROM is taken, including (i) how the BROM II would be placed on the subjects, (ii) how the subjects moved their body, and (iii) consistent verbal instruction. Using this video in one part of the protocol may have improved the reliability of the measured LROM. This study aimed to determine the inter-rater and test–retest reliability of the protocol to measure LROM using the BROM II.

Subjects and methods

Subjects

Twenty healthy subjects (10 males and 10 females) who met the inclusion criteria participated in this study. The subjects were randomly selected from undergraduate and graduate students who were enrolled in the Physical Therapy program, Faculty of Allied Health Sciences, Chulalongkorn University. The inclusion criteria were as follows: (i) no low back pain over the last 2 months, (ii) no history of trauma or fracture of the lumbar spine, and (iii) no spinal surgery. The sample size was calculated based on the sample size calculator (Version 1.5.1) designed by Walter et al. [16]. The observation = 5, α error probability = 0.05, power = 0.80, acceptable reliability = 0.75, and expected reliability = 0.90 were set, which resulted in the calculation that a minimum of 15 sub-

Table 1. Characteristics of twenty healthy subjects

Characteristics	Mean ± *SD*	95% CI	Minimum–Maximum
Age (years)	24.8 ± 3.7	23.18–26.41	20–30
Weight (kg)	58.8 ± 11.6	53.69–63.87	44.5–94.4
Height (m)	1.63 ± 0.07	1.59–1.66	1.53–1.75
BMI (kg/m^2)	21.85 ± 3.25	20.43–23.27	18.00–32.20
Foot angle [*n*/20 (%)]			
4°	6/20 (30.00)		–
8°	11/20 (55.00)		–
12°	3/20 (15.00)		–

CI – confidence interval

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Received: 16.04.2022
Accepted: 27.10.2022

Citation: Suriyaamarit D, Leevattananukool P, Chiradejnant A. Test–retest and inter-rater reliability of lumbar range of motion procedure using back range of motion instrumentt. Physiother Quart. 2024;32(1):73–77; doi: https://doi.org/10.5114/pq.2024.135426.

jects would be required. The characteristics of the subjects are presented in Table 1.

Procedure

In the present study, a BROM II™ (Performance Attainment Associates, Roseville, Minn, USA) was used to measure the LROM. Briefly, the BROM II consists of two parts. First, the flexion/extension unit is responsible for measuring movements in the sagittal plane (Figure 1A). Second, the rotation and lateral flexion unit (R/L unit) consists of a gravity goniometer, and a compass is responsible for measuring movements in the frontal and transverse planes (Figure 1B).

Five physical therapists who worked at the Physical Therapy Clinic of the university and had more than 1 year of clinical experience (5.20 ± 3.83 years) were recruited by the convenience sampling method; hereafter called the 'raters'. Before the data collection, the raters and subjects were asked to watch a 4-minute video clip to understand the details of this study. The 4-minute video clip consisted of three parts: (1) finding reference points, (2) starting position, and (3) verbal instructions and how to perform the movements.

Part 1 showed finding the reference points, which consisted of the base of the sacrum and the spinous process of thoracic spine level 12. The base of the sacrum was located by drawing a line between the posterior superior iliac spine (PSIS) (the same level as the S2 spinous process) and counting up from the base of the sacrum. The spinous process of thoracic spine level 12 was located by counting up six levels from the 1st reference point. These two references were used to place the flexion/extension unit and the BROM R/L unit.

Part 2 of the video showed the starting position. All movements were tested in a standing position, except lumbar rotation, which was tested in a sitting position. The subjects were asked to stand on a foam board in a comfortable position. Then, the foot positions were marked. The comfortable foot positions were selected and determined between the long axes of each foot and the longitudinal line in the sagittal

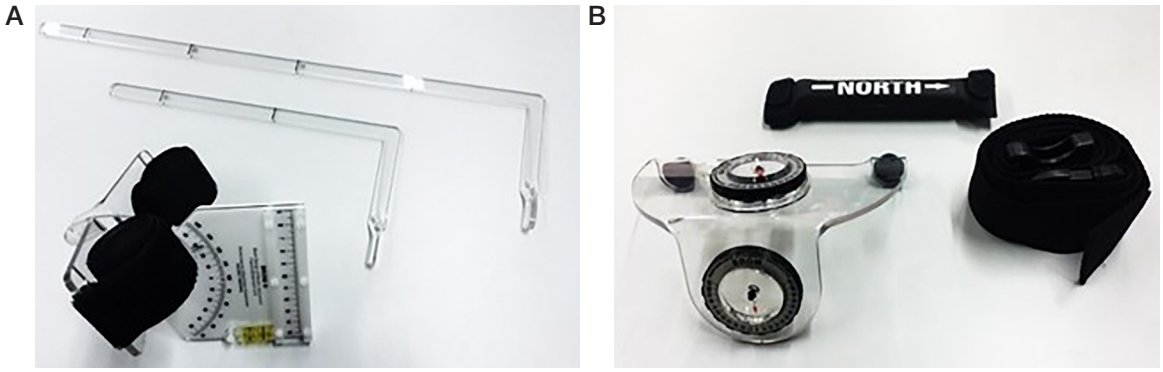

Figure 1. BROM II: A – flexion/extension unit and the L-shaped slide arm, B – BROM R/L unit, magnetic reference and belt

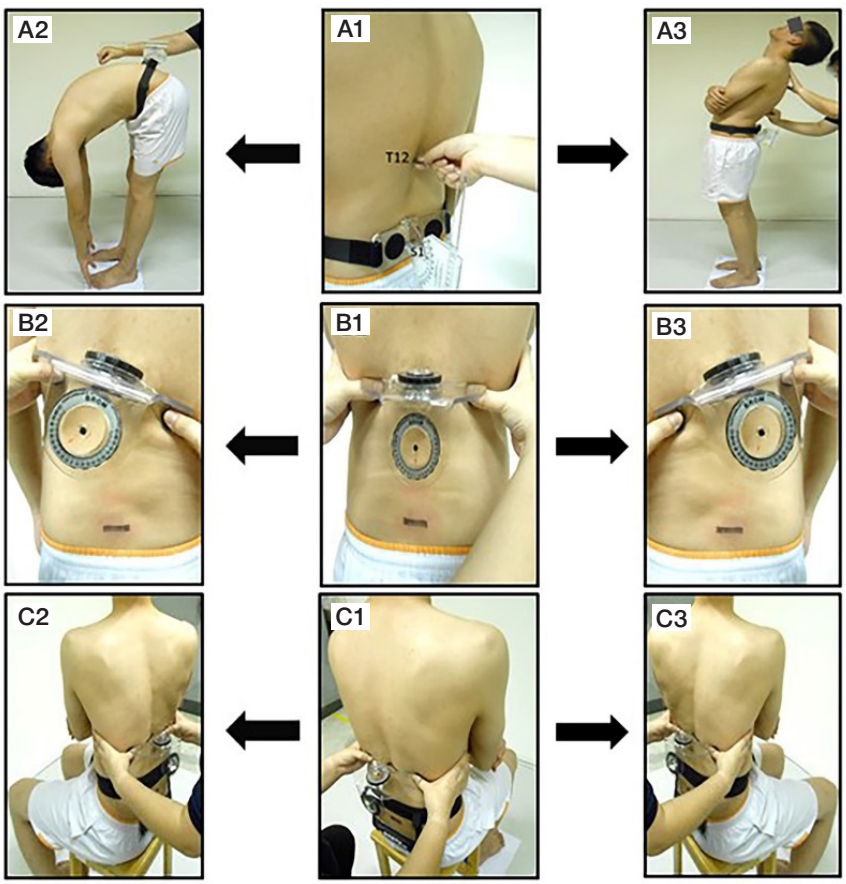

Figure 2. Set A: A1 represents the starting position, A2 represents flexion, and A3 represents extension,
Set B: B1 represents the starting position, B2 represents right lateral flexion, and B3 represents left lateral flexion,
Set C: C1 represents the starting position, C2 represents right rotation, and C3 represents left rotation

plane (4°, 8° or 12°) with the heels placed 17 centimetres apart [17].

Part 3 showed the verbal instructions and the movements of the lumbar spine in six directions, as follows:

Flexion: Bend forwards as far as possible while keeping the knees extended, trying to reach your fingertips to the floor. Return to the starting position.

Extension: Crossing your arms, bend backwards as far as possible while keeping your knees extended. Return to the starting position.

Left/right lateral flexion: Laterally bend to left/right side as far as possible by sliding the left/right hand down the side of the left/right leg. Do not rotate the trunk while performing the movement. Return to the starting position.

Left/right rotation: Crossing your arms, rotate your trunk to the left/right as far as possible. Do not laterally bend while performing the movement. Return to the starting position.

After watching the video clip, the raters marked the reference points and set the starting positions of the subjects. The Latin square design was then used to arrange the rater order to prevent bias of the sequence of measurements. Measurements, including lumbar flexion, extension, left and right lateral flexion, and left and right rotation, are presented in Figure 2.

During the LROM measurement, all subjects were allowed to practice all lumbar movements once. The measurements were noted on the next trial in the order of flexion, extension, left lateral flexion, right lateral flexion, left rotation, and right rotation. The raters corrected the position of the device regularly during the assessment. Each rater measured the subjects' LROM twice to allow test–retest reliability evaluation. Measurements took place at a maximum time interval of 1 days. This time interval was selected not only to prevent any incidence of back pain but also prevent bias of their own results. Additionally, all raters were blinded to their own results.

Statistical analysis

All data were analysed using the Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL, USA) version 22 for Windows. The intraclass correlation coefficient (ICC) was used for this study. The test–retest and interrater reliability were investigated using [$ICC_{(3,1)}$] (two-way mixed model) and [$ICC_{(2,1)}$] (two-way random model), respectively. The second trial data from each rater were used to calculate the inter-rater reliability. The ICC values were interpreted as follows: values less than 0.25 represent no reliability, 0.25–0.50 represent fair reliability, 0.50–0.75 represent moderate-to-good reliability, and more than 0.75 represent good-to-excellent reliability [18]. In addition, the standard error of the measurement (SEM) was determined with the following equation: $SEM = SD \times \sqrt{(1 - ICC)}$. The minimal detectable change (MDC) at the 95% CI was determined with the following equation: $MDC = 1.96 \times SEM \times \sqrt{2}$.

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 Ethical review committee for research involving human subjects and/or use of animal in research, Chulalongkorn University, Thailand (COA No.123/2554).

Informed consent

Informed consent has been obtained from all individuals included in this study or from their legal guardians.

Results

Test–retest reliability

For the test–retest reliability, the ICC values were good-to-excellent, ranging from 0.86 to 0.98 for flexion, 0.93 to 0.97 for extension, 0.87 to 0.97 for left lateral flexion, 0.90 to 0.95 for right lateral flexion and 0.82 to 0.94 for left rotation. The results of this study were moderate-to-good, ranging from 0.74 to 0.97, for right rotation. In addition, the SEM and MDC values ranged from 0.87 to 2.13 and 2.41 to 5.90 degrees for flexion, 0.85 to 1.20 and 2.37 to 3.33 degrees for extension, 0.78 to 1.27 and 2.15 to 3.52 degrees for left lateral flexion, 0.95 to 1.23 and 2.64 to 3.40 degrees for right lateral flexion, 0.55 to 0.95 and 1.52 to 2.63 degrees for left rotation, and 0.32 to 0.78 and 0.88 to 2.15 degrees for right rotation. The intra-rater reliability, SEM and MDC of the LROM measurement using the BROM II are presented in Table 2.

Inter-rater reliability

For the inter-rater reliability, the ICC values were good-to-excellent in all directions reported: 0.86 for flexion, 0.87 for extension, 0.79 for left lateral flexion, 0.87 for right lateral flexion, 0.78 for left rotation and 0.79 in right rotation. In addition, the SEM and MDC values were reported as 2.02 and 5.60 degrees for flexion, 1.67 and 4.64 degrees for extension, 1.70 and 4.71 degrees for left lateral flexion, 1.58 and 4.37 degrees for right lateral flexion, 1.00 and 2.77 degrees for left rotation, and 0.79 and 2.19 degrees for right rotation. The inter-rater reliability, SEM and MDC of the LROM measurement using the BROM II are presented in Table 3.

Discussion

This study aimed to investigate the inter-rater and test–retest reliability of the protocol to measure LROM using the BROM II. The results demonstrated that the ICC values in both test–retest and inter-rater reliability of the LROM measurement using the BROM II in all directions were good-to-excellent, ranging from 0.82 to 0.98, except that the test–retest reliability of the LROM in the right rotation was moderate-to-good, ranging from 0.74 to 0.97. The moderate-to-good test reliability of LROM in the right rotation direction might have occurred due to the subjects' inability to apply equal hand pressure on the contact points. This explanation was similar to the previous study by Kachingwe and Phillips [7].

In the current study, we controlled the errors from the raters and subjects as far as possible [7, 10, 14]. For example, the study used a standardised protocol to identify the reference points, starting position, and consistent verbal instructions and movements. Although one previous study [7] described reference points, a rater who is inexperienced or lacks palpation skills may be in error. Mayer et al. [19] reported that the largest source of error in ROM measurement was a lack of practice among test administrators. To reduce the rater error, the details of this study were fully explained to the raters, who were asked to watch a 4-minute video clip and practice how to note LROM using the BROM II to ensure that the lumbar ROM movements were identical. In addition, a previous study reported that a potential source of error with the device was slippage of the device on clothing during lumbar flexion and extension measurements [14]. In this study, the device was applied directly to the skin, and the rater repeatedly adjusted the device's position during the assessment.

Table 2. Test–retest reliability, SEM and MDC of the lumbar range of motion measurement using back range of motion instrument (BROM II)

Movement	Trial 1 (°) mean ± *SD*	Trial 2 (°) mean ± *SD*	ICC $_{(3,1)}$ (95% CI)	SEM (°)	MDC (°)
Flexion					
Rater 1	28.10 ± 5.49	27.80 ± 5.27	0.95 (0.88–0.98)	1.18	3.27
Rater 2	28.45 ± 5.38	28.65 ± 5.08	0.94 (0.86–0.98)	1.27	3.52
Rater 3	27.89 ± 5.70	26.95 ± 5.52	0.86 (0.67–0.94)	2.13	5.90
Rater 4	27.95 ± 5.62	27.45 ± 5.61	0.98 (0.93–0.99)	0.87	2.41
Rater 5	27.10 ± 6.08	27.60 ± 5.50	0.89 (0.75–0.96)	1.90	5.26
Extension					
Rater 1	8.45 ± 4.58	8.20 ± 4.18	0.94 (0.85–0.98)	1.09	3.02
Rater 2	7.75 ± 4.29	8.00 ± 4.82	0.97 (0.92–0.99)	0.85	2.37
Rater 3	8.35 ± 5.04	8.30 ± 4.94	0.97 (0.92–0.99)	0.91	2.51
Rater 4	8.65 ± 5.51	8.20 ± 4.97	0.95 (0.88–0.98)	1.17	3.25
Rater 5	7.90 ± 4.78	7.40 ± 4.24	0.93 (0.83–0.97)	1.20	3.33
Left lateral flexion					
Rater 1	28.50 ± 3.30	28.00 ± 3.18	0.90 (0.76–0.96)	1.04	2.90
Rater 2	28.30 ± 3.33	28.10 ± 3.58	0.87 (0.69–0.94)	1.27	3.52
Rater 3	27.80 ± 4.35	27.30 ± 3.69	0.93 (0.84–0.97)	1.04	2.89
Rater 4	28.80 ± 4.37	28.40 ± 4.19	0.97 (0.92–0.99)	0.78	2.15
Rater 5	29.70 ± 3.57	29.50 ± 3.83	0.94 (0.86–0.98)	0.89	2.47
Right lateral flexion					
Rater 1	26.60 ± 4.55	26.40 ± 4.92	0.95 (0.87–0.98)	1.10	3.05
Rater 2	26.90 ± 4.18	26.40 ± 4.57	0.93 (0.84–0.97)	1.14	3.17
Rater 3	25.90 ± 3.97	26.20 ± 4.10	0.92 (0.81–0.97)	1.14	3.16
Rater 4	26.50 ± 3.99	26.80 ± 3.91	0.90 (0.78–0.96)	1.23	3.40
Rater 5	27.80 ± 3.83	28.10 ± 4.28	0.95 (0.87–0.98)	0.95	2.64
Left rotation					
Rater 1	8.40 ± 2.30	8.70 ± 2.18	0.90 (0.77–0.96)	0.71	1.96
Rater 2	9.30 ± 2.36	9.60 ± 1.90	0.90 (0.58–0.92)	0.95	2.63
Rater 3	9.60 ± 2.39	9.50 ± 2.04	0.94 (0.85–0.98)	0.55	1.52
Rater 4	8.70 ± 1.63	9.10 ± 2.00	0.82 (0.60–0.93)	0.77	2.13
Rater 5	9.00 ± 2.29	9.00 ± 2.47	0.93 (0.83–0.97)	0.64	1.76
Right rotation					
Rater 1	9.10 ± 1.77	9.20 ± 1.77	0.97 (0.92–0.99)	0.32	0.88
Rater 2	8.90 ± 1.77	9.00 ± 1.65	0.97 (0.92–0.99)	0.32	0.88
Rater 3	9.70 ± 2.08	9.60 ± 2.11	0.93 (0.84–0.97)	0.55	1.52
Rater 4	9.00 ± 1.52	9.20 ± 1.51	0.74 (0.45–0.89)	0.78	2.15
Rater 5	9.00 ± 1.38	9.30 ± 1.49	0.86 (0.67–0.94)	0.54	1.51

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

Table 3. Inter-rater reliability, SEM and MDC of the lumbar range of motion measurement using back range of motion instrument (BROM II)

Movement	Rater 1 mean ± *SD*	Rater 2 mean ± *SD*	Rater 3 mean ± *SD*	Rater 4 mean ± *SD*	Rater 5 mean ± *SD*	ICC $_{(2,1)}$ (95% CI)	SEM (°)	MDC (°)
Flexion (°)	27.80 ± 5.27	28.65 ± 5.08	26.95 ± 5.52	27.45 ± 5.61	27.60 ± 5.50	0.86 (0.76–0.94)	2.02	5.60
Extension (°)	8.20 ± 4.15	8.00 ± 4.82	8.30 ± 4.94	8.20 ± 4.97	7.40 ± 4.24	0.87 (0.77–0.94)	1.67	4.64
Left lateral flexion (°)	28.00 ± 3.18	28.10 ± 3.58	27.30 ± 3.69	28.40 ± 4.19	29.50 ± 3.83	0.79 (0.64–0.90)	1.70	4.71
Right lateral flexion (°)	26.40 ± 4.92	26.40 ± 4.57	26.20 ± 4.10	26.80 ± 3.91	28.10 ± 4.28	0.87 (0.76–0.94)	1.58	4.37
Left rotation (°)	8.70 ± 2.18	9.60 ± 1.90	9.50 ± 2.04	9.10 ± 2.00	9.00 ± 2.47	0.78 (0.64–0.89)	1.00	2.77
Right rotation (°)	9.20 ± 1.77	9.00 ± 1.65	9.60 ± 2.11	9.20 ± 1.51	9.30 ± 1.49	0.79 (0.66–0.90)	0.79	2.19

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

The subjects viewed the demonstration video and practiced all lumbar movements before the data collection to reduce subject error. To improve the reliability, the standardised protocol was strictly followed by controlling the starting position of the subjects' feet in comfortable positions adopted from a previous study [17]. Instead of using preferred foot positions, which yielded more variable results, the subjects were asked to choose their comfortable foot positions among three predetermined positions of 4°, 8° and 12°. These positions were set to the angle between the long axis of the foot and the line in the sagittal plane.

Limitations

There are notable limitations to this study. One is that the subjects were currently asymptomatic persons. In contrast, clinical implementation has been measuring LROM in patients with low back pain. Repeated movement of the lumbar spine can affect the back pain of the patients. Therefore, spinal movement may reflect the patient-perceived abilities to move through the available ROM. In addition, the LROM procedure using the BROM II may not be suitable for subjects who are short-waisted or have hypermobility, such as gymnasts. The flexion/extension unit and the L-shaped slide arm may limit lumbar movement in some directions, especially in lumbar extension. However, this condition was not found in this study. For clinical implications, the results of this study show that the LROM procedure was reliable in measuring LROM. Thus, these results may provide useful information for designing an LROM measurement protocol using BROM II.

Conclusions

In conclusion, the test–retest and inter-rater reliability of the LROM procedure obtained by the BROM II were reliable and suitable for research. The LROM procedure consisted of a 4-minute video clip, practice of all lumbar movements before measuring, and consistent verbal instruction.

Acknowledgements

This study was supported in part by the Asian research Center of the Korea Foundation for Advanced Studies, Chulalongkorn University, under Grant number 002/2562.

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.

Funding

This research received no external funding.

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