The Egyptian Journal of Hospital Medicine (January 2024) Vol. 94, Page 988-993

Validity and Reliability of an iPhone® Clinometer Application for Assessment of Joint Repositioning Error in Patients with Non-Specific Chronic Low Back Pain

Nada Elsayed Ahmed Mohamed*[1], Salwa Fadl Abdelmegeed[2], Aya A. Khalil[1], Dina S. Abd Allah[2], Mohamed Abdelmegeed[2]

Departments of [1]Biomechanics and [2]Physical Therapy for Musculoskeletal System Disorders and Its Surgery, Faculty of Physical Therapy, Cairo University, Egypt

***Corresponding author:** Nada Elsayed Ahmed Mohamed, **Mobile:** (+20) 01007800902, **E-mail:** nadaelsayed95@gmail.com

ABSTRACT

Background: Non-specific chronic low back pain (NSCLBP) is a complex issue that impacts an individual's quality of life and functionality, leading to impairments in somatosensory and proprioception. Errors in proprioception are evaluated using specific tests such as joint reposition sense.

Objective: This study aimed to validate and determine the reliability of the iPhone inclinometer application (Clinometer) in measuring the error in lumbar joint repositioning in patients suffering from NSCLBP.

Materials and methods: In this cross-sectional study, 55 male and female patients diagnosed with NSCLBP were involved, with an average age of 25.51 ± 6 years. All patients underwent an active lumbar repositioning test using the Clinometer application and an isokinetic dynamometer to calculate the absolute angular error for a target angle of 30° lumbar flexion. This was done over two assessment sessions on different days, with each patient being evaluated by two examiners at each session. The intra-rater and inter-rater reliability were determined using the Intraclass Correlation Coefficient (ICC), and the concurrent validity was tested using Spearman's correlation.

Results: The Clinometer application demonstrated excellent concurrent validity with the isokinetic measurements at the same target angle ($r= 0.83$, $p< 0.01$), and exhibited excellent intra and inter-rater reliability (ICC values ranged from 0.88 to 0.93 for intra-rater reliability and from 0.82 to 0.88 for inter-rater reliability).

Conclusion: The Clinometer app is a viable and reliable alternative to the isokinetic dynamometer for evaluating active lumbar reposition sensation in persons with NSCLBP at 30˚ of flexion.

Keywords: Joint reposition sense, LBP, Proprioception, Reliability, Validity.

INTRODUCTION

NSCLBP is described as chronic pain in the back and sacrum lasting more than 12 wks. It has emerged as a leading cause of disability among adults, impacting their functionality and quality of life [1, 2].

It affects approximately 12-33% of the adult population, with 85% of chronic LBP cases being non-specific, meaning they lack identifiable physiological, neural, or orthopaedic disorders in the spine [3].

Joint position sense (JPS) is one test used to measure proprioception, which is the awareness of joint and body movement as well as the location of the body or its parts in space [4, 5].

The JPS test is frequently used to assess a participant's accuracy in reproducing a lumbar spine "target position" that is provided via verbal, physical, or visual cues. The subject is taken out of the position and asked to actively recreate the goal position once it is given [6]. Prior studies have utilized complex, expensive, and non-portable equipment like video analysis systems and isokinetic dynamometers, which are challenging to use in clinical settings [7].

According to recent comprehensive reviews, patients with NSLBP have much worse lumbopelvic proprioceptive acuity than people without symptoms [4, 8]. Individuals with NSCLBP have been shown to have both functional (e.g., disrupted neuromuscular coordination between the deep and superficial back muscles) and structural (e.g., muscle atrophy and fat infiltration) alterations in the trunk muscles [9]. These modifications cause impairments in tactile selective acuity and proprioception, which impair motor function, upset segmental spinal stability, and eventually cause greater pain and articular injury [10].

Gaining an understanding of these mechanisms in individuals with LBD may be essential to enhance back pain care, particularly with regard to making correct diagnoses, delivering a believable explanation for the issue, providing pertinent information, and recommending efficient rehabilitation techniques [11].

This study was therefore conducted to aid in the development of a smartphone-based measurement of JPS of lumbar flexion, using a portable and simple tool to measure proprioceptive deficits in patients with NSCLBP conveniently and cost-effectively.

MATERIALS AND METHODS

Participants: A cross-sectional study that was conducted through the period from April to September 2023. A calculation was carried out to determine the necessary sample size for the study, which was conducted at the Outpatient Clinic of the Faculty of Physical Therapy at Cairo University, Egypt.

Inclusion criteria: Age between 18 and 45 years, had NSCLBP for more than three months, had pain that was either referred to the leg or between the costal margins and the inferior gluteal folds, and had scored at least three on the numerical pain rating scale (NPRS), which goes from zero for no pain to ten for the worst possible pain.

Received: 23/10/2023
Accepted: 20/12/2023

Exclusion criteria: Pregnancy (including up to 6 months after giving birth), any history of back or lower limb surgery, neuropathic pain, recent trauma to the back or lower extremities, the presence of metal spine implants, neurological or vestibular disorders and a diagnosed psychiatric disorder, or severe cognitive impairment.

Procedure: Demographic data such as age, gender, height, and weight were collected. JPS was evaluated using an isokinetic Dynamometer and an iPhone application called Clinometer. Each patient was assessed twice by two different examiners, with a maximum of three working days between the two sessions. Both sessions were conducted in the same manner and at the same time of day.

The assessment of proprioception began with the isokinetic system measuring JPS through an active joint repositioning test. The individual taking the test was sat in the chair of the Biodex system. Two curved anterior leg pads were used to modify the knee block locations, and two straps were used to stabilise each thigh.

A pelvic brace was placed across the top portion of the proximal thighs, pressing forcefully yet pleasantly. The lower lumbar spine was supported by a lumbar pad. After elevating the seat one inch forward, the actuator arm's axis was adjusted to line with the L5/S1 disc space, which is clinically recognised by palpating the posterior superior iliac spine (PSIS), which is located at the S2 level. A belt secured the upper section of the trunk to the rear attachment. To guarantee a uniform beginning position for all participant's three testing trials, the dynamometer was locked at the 0° position [(12)].

Every participant completed three test repetitions during the practice phase of the testing process. The practice trial came to an end, and then the actual test started. The dynamometer gently put each participant into a 30° lumbar flexion posture for 10 seconds throughout the session, and the subject was told to recall the position. The investigator then passively moved the joint back to its starting position, and the participants were instructed to replicate the goal joint position as closely as possible. Figure (1) showed the recorded angles that were recreated. Throughout the measurements, all individuals wore eye masks to block off visual information. The average of the three measurements was taken after, this step was completed three times. Between each measurement, there was a long enough rest interval (20 seconds) to prevent tiredness [(13)].

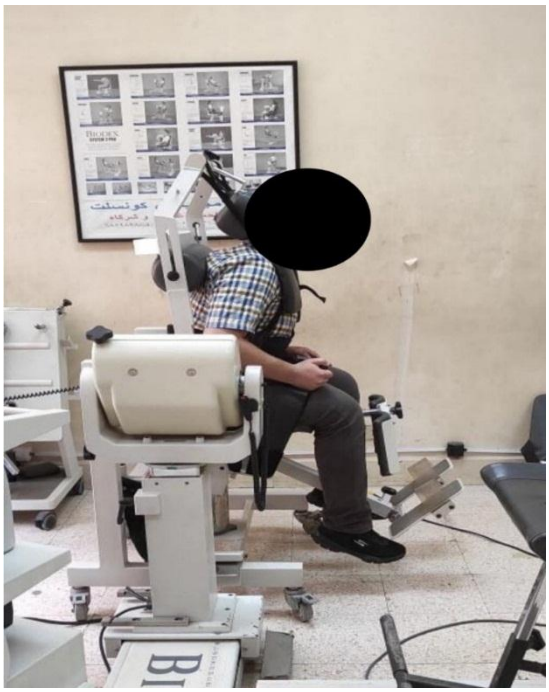

Figure (1): Isokinetic JPS measurement at 30˚ lumbar flexion.

Two examiners took the measurements. For each assessment session, the participants performed the test with one examiner, followed by a short break of approximately 10 minutes. After the break, the participant performed the same test with the second examiner [(7)].

Randomization was used to arrange the assessments such that no examiner assessed every patient in advance [(4)].

Each participant attended two separate sessions with a maximum of three working days between the sessions, and the two sessions were conducted in the same manner and at the same time of day [(7)].

The iPhone® was placed vertically, halfway between the anterior superior and PSIS, just above the iliac crest, and fastened with a belt. The initial location and the inclination of the inclinometer were both fixed at 0° (Figure 2). There was a 0 to 30° range of motion (ROM). The assessor gently guided the individual to a 30° flexion and instructed them to hold this posture for ten seconds. After then, the participant actively went back to their starting location and subsequently did it three times [(13)].

Figure (2): Clinometer JPS measurement at 30˚ lumbar flexion.

During the active joint repositioning test, the proprioceptive errors reported by both the isokinetic and the inclinometer's concurrent validity during the JPS test were calculated by comparing the applications. The proprioceptive error was quantified as an absolute angular error (AAE), is the amount of variation from the reference angle (30° flexion), measured without taking the error's direction into account. For statistical analysis, the absolute angular mean (AAM), which is the mean of the three observations, was employed.

The same process was repeated to calculate the AAE and AAM. The results of the proprioceptive errors reported by the isokinetic and the application were again compared to compute the concurrent validity of the inclinometer during the JPS test. The results reported by the first and second examiners were compared to establish inter-class reliability. The results of the proprioceptive error reported by the first examiner in the first session were compared with those from the second session to establish intra-class reliability, and the same process was repeated for the second examiner.

Ethical approval: The Institutional Review Board of the Faculty of Physical Therapy, Cairo University approved the study (approval No.: P.T.REC/ 012/ 004518, approval date: March 4, 2023). Before the study began, each participant was informed about the study's procedures and objectives. Each participant gave written consent after receiving all information. The Helsinki Declaration was followed throughout the study's conduct.

Statistical analysis

Version 23.0 of SPSS was used for all statistical analyses. 0.05 was chosen as the alpha threshold. Pearson's correlation coefficient was used to assess concurrent validity. A correlation of r <0.25 denoted little to no association, r >0.25 to r <0.50 denoted a fair relationship, r >0.50 to r <0.75 denoted a moderate to good link, and r > 0.75 denoted a good to excellent relationship. The intraclass correlation coefficient (ICC), which ranged from <0.40 to <0.60 for poor to fair, 0.41 to 0.60 for moderate, 0.61 to 0.80 for excellent, and 0.81 to 1.00 for nearly perfect, was used to compare the intra- and inter-rater reliabilities. The SPSS options were limited to a two-way mixed model effect model and absolute agreement. To find the degree of agreement between measurements, the Bland-Altman plot was employed. Statistical significance was attained in all analyses with a p-value ≤ 0.05.

RESULTS

Characteristics of patients: The study included 55 patients, comprising 5 males and 50 females, all diagnosed with NSCLBP. They had a mean age of 25.51± 6.09 years, mean BMI of 24.92 ± 4.59 kg/m^2 and mean VAS of5.76 ± 1.51 (Table 1).

Table (1): Demographic data of the patients.

Study group	Mean	S. D.	Minimum value	Maximum value
Age (years)	25.51	6.09	18	45
Body mass index (Kg/m^2)	24.92	4.59	17.60	41
Pain (VAS)	5.76	1.51	3	9

Validity: The measurements of the lumbar joint repositioning error in patients with NSCLBP, taken at a target angle of 30° flexion using the iPhone application, demonstrated excellent concurrent validity with the isokinetic measurements at the same target angle (r= 0.83, p< 0.01) as shown in (Table 2).

Table (2): Correlation between overall average Isokinetic and iPhone measurements

	Age	BMI	Pain (VAS)	Isokinetic Measurements
iPhone Measurements	0.37**	0.23	0.29*	0.83**

*Correlation is significant at p-value ≤ 0.05 (2-tailed)
** Correlation is significant at p-value ≤ 0.01 (2-tailed)

Reliability: The iPhone application's measurements of the lumbar joint repositioning error in patients with NSCLBP, taken at a target angle of 30° flexion, exhibited excellent intra-rater reliability (ICC= 0.88 to 0.93) as depicted in tables (3) and (4), and relatively excellent inter-rater reliability (ICC= 0.82 to 0.88) as shown in tables (5) and (6).

Table (3): Intraclass Correlation Coefficient of the 1st examiner using the iPhone application

	Mean ±SD	**ICC 95% CI (lower-upper bound)**	**SEM**	**MDC_{90}**	**MDC_{95}**
First measurement	3.15±2.00	0.93 (0.89 - 0.96)	0.48	1.11	1.32
Second measurement	3.13±1.71				

SD: Standard deviation, **ICC**: intraclass correlation coefficient, **SEM**: Standard error of the mean, **MDC_{90}**: Minimal Detectable Change at 90% confidence, **MDC_{95}**: Minimal Detectable Change at 95% confidence.

Table (4): Intraclass Correlation Coefficient of the 2nd examiner using the iPhone application

	Mean ±SD	**ICC 95% CI (lower-upper bound)**	**SEM**	**MDC_{90}**	**MDC_{95}**
First measurement	3.58 ± 1.90	0.88 (0.80 – 0.93)	0.61	1.42	1.69
Second measurement	3.25 ± 1.69				

SD: Standard deviation, **ICC**: intraclass correlation coefficient, **SEM**: Standard error of the mean, **MDC_{90}**: Minimal Detectable Change at 90% confidence, **MDC_{95}**: Minimal Detectable Change at 95% confidence

Table (5): Inter-rater reliability between the 2 examiners in the 1st session using the iPhone application

	Mean ±SD	**ICC 95% CI (lower-upper bound)**	**SEM**	**MDC_{90}**	**MDC_{95}**
Examiner 1 measurement	3.15±2.00	0.82 (0.69 - 0.90)	0.83	1.94	2.30
Examiner 2 measurement	3.58±1.90				

SD: Standard deviation, **ICC**: intraclass correlation coefficient, **SEM**: Standard error of the mean, **MDC_{90}**: Minimal Detectable Change at 90% confidence, **MDC_{95}**: Minimal Detectable Change at 95% confidence.

Table (6): Inter-rater reliability between the 2 examiners in the 2nd session using the iPhone application

	Mean ±SD	**ICC 95% CI (lower-upper bound)**	**SEM**	**MDC_{90}**	**MDC_{95}**
Examiner 1 measurement	3.13±1.71	0.88(0.80 - 0.93)	0.58	1.35	1.61
Examiner 2 measurement	3.25±1.69				

SD: Standard deviation, **ICC**: intraclass correlation coefficient, **SEM**: Standard error of the mean, **MDC_{90}**: Minimal Detectable Change at 90% confidence, **MDC_{95}**: Minimal Detectable Change at 95% confidence.

DISCUSSION

The study's goals were to assess the validity and reliability of an iPhone application, clinometer, in measuring the active lumbar JPS in NSCLBP at a target angle of 30˚ of lumbar flexion. Unfortunately, none of the previous research that the authors are aware of have documented employing this exact application in this field.

Concurrent validity:

The primary outcome of this study was that the clinometer application's measurements of JPS, taken in a seated position with 30° lumbar flexion, demonstrated excellent validity in patients with NSCLBP when compared to the isokinetic dynamometer measurements. Similar results were reported in previous studies that evaluated whether the clinometer application's concurrent validity for utilising a motion capture system to measure the joint's ROM and JPS was fulfilled [7, 12, 13]. According to **Kaur *et al.*** [14]**,** at lower humeral elevation angles, the clinometer app is a useful tool for monitoring scapular tilt and upward rotation, as compared to an electromagnetic motion capture system. Our results align with those of **Ganokroj *et al.*** [15]**,** who with two examiners, the same clinometer application was used to measure passive hip internal and external rotation (ER) in sitting and prone positions. They got to the conclusion that the validity was good to outstanding for IR angles in all locations (ICC=0.81-0.94) after comparing the data with those from three-dimensional motion analysis cameras. Furthermore, **Werner *et al.*** [16] found that, when evaluating shoulder ROM in both healthy individuals and patients with symptoms, the smartphone clinometer and a goniometer agree quite well. In a similar vein, shoulder IR and ER measurements using the clinometer smartphone application and a handheld goniometer showed no differences [17]. Additionally, while evaluating hip and knee ROM in young, healthy females, the clinometer showed good validity and reproducibility [18]. In the study by **Miley *et al.*** [19]**,** the clinometer smartphone application produced similar results, showing a very strong relationship for IR (r=0.94-0.96) and ER (r=0.84-0.89) when active hip rotation was measured by a goniometer. **Cox *et al.*** [20] studied the clinometer smartphone application's validity with a universal plastic goniometer in ankle plantar flexion ROM and demonstrated that the clinometer smartphone application was a valid instrument. The application was previously used for assessing cervical ROM by **Monreal *et al.*** [21] against a universal goniometer. They attested to the accuracy of the clinometer application in assessing the cervical spine's active ROM in flexion, extension, lateral flexion, and rotation.

Intra-rater and inter-rater reliability:

Secondly, our study found that both the intra-rater and inter-rater reliability of the clinometer application were excellent when measuring at 30˚ of lumbar flexion. In agreement with our findings in spinal assessment, **Hwang *et al.*** [22] used four devices to assess thoracic spine rotation in healthy persons. They use a goniometer, a bubble inclinometer, a dual inclinometer, and the clinometer smartphone application. They discovered that the dual inclinometer and the smartphone clinometer had higher intra-rater reliability than the other two devices, while the smartphone clinometer had the second greatest inter-rater reliability among the four devices. Furthermore, when the same application was used to measure upper cervical ROM, it showed high interphone/examiner reliability (0.87, 0.81) and interphone/examiner reliability across three trials [21, 23].

The clinometer smartphone application showed similar reliability results in different joints. The programme revealed strong intra-rater reliability for shoulder ROM evaluation in both healthy and sick patients [15]. Scapular upward rotation was measured with moderate to high inter-rater reliability [14]. The clinometer application revealed great reliability (ICC > 0.90) for hip and knee sagittal plane motion, as well as moderate reliability for ankle sagittal plane motion [17]. Additionally, it demonstrated high to exceptional intra-rater reliability for active hip IR and ER [19].

CONCLUSIONS

The iPhone application, clinometer was a valid and reliable substitute for the isokinetic dynamometer in measuring active lumbar JPS in patients with NSCLBP at a target angle of 30˚ of lumbar flexion. The clinometer application could be utilized by physiotherapists in the assessment process of JPS in patients with NSCLBP.

ACKNOWLEDGEMENTS

The authors would like to thank the head of Laboratory Biomechanics, Faculty of Physical Therapy, Cairo University, for providing the chance to conduct this research. The authors also like to sincerely thank each and every patient who took part in the research.

REFERENCES

1. **Prent J, van der Wurff P, Scholten-Peeters G (2023):** Lifestyle factors and psychological factors are associated with central pain processing in service members with persistent low-back pain: A cross-sectional exploratory study. Medicine, 102 (51): e36741. doi: 10.1097/MD.0000000000036741.
2. **Alsufiany M, Lohman E, Daher N *et al.* (2020):** Non-specific chronic low back pain and physical activity: A comparison of postural control and hip muscle isometric strength: A cross-sectional study. Medicine, 99 (5): e18544. doi: 10.1097/MD.0000000000018544.

3. **ALMohiza M, Reddy R, Asiri F *et al.* (2023):** The Mediation Effect of Pain on the Relationship between Kinesiophobia and Lumbar Joint Position Sense in Chronic Low Back Pain Individuals: A Cross-Sectional Study. Int J Environ Res Public Health, 20 (6): 5193. doi: 10.3390/ijerph20065193.
4. **Caña-Pino A, Espejo-Antúnez L, Adsuar J *et al.* (2021):** Test-Retest Reliability of an iPhone® Inclinometer Application to Assess the Lumbar Joint Repositioning Error in Non-Specific Chronic Low Back Pain. Int J Environ Res Public Health, 18 (5): 2489. doi: 10.3390/ijerph18052489.
5. **Yang Q, Wang X (2023):** Lumbar joint position sense measurement of patients with low back pain. EFORT Open Rev., 8 (8): 639-650.
6. **Fathy M, Abd-Allah D, Mohamed N *et al.* (2023):** Validity and Reliability of Digital Inclinometer for Assessment of Joint Position Sense in Patients with Knee Osteoarthritis. Egyptian Journal of Physical Therapy, 14: 16-21.
7. **Korakakis V, O'Sullivan K, Kotsifaki A *et al.* (2021):** Lumbo-pelvic proprioception in sitting is impaired in subgroups of low back pain-But the clinical utility of the differences is unclear. A systematic review and meta-analysis. PLoS One, 16 (4): e0250673. doi: 10.1371/journal.pone.0250673.
8. **Fortin M, Rye M, Roussac A *et al.* (2021):** The effects of combined motor control and isolated extensor strengthening versus general exercise on paraspinal muscle morphology and function in patients with chronic low back pain: a randomised controlled trial protocol. BMC Musculoskelet Disord., 22 (1): 472. doi: 10.1186/s12891-021-04346-x.
9. **Wattananon P, Thu K, Maharjan S *et al.* (2023):** Cortical excitability and multifidus activation responses to transcranial direct current stimulation in patients with chronic low back pain during remission. Sci Rep., 13 (1): 16242. doi: 10.1038/s41598-023-43597-7.
10. **Klerx S, Mokkink L, Coppieters M *et al.* (2023):** Reliability of two lumbar motor control tests for people with low back pain that are feasible in clinical practice. Musculoskelet Sci Pract., 66: 102775. doi: 10.1016/j.msksp.2023.102775.
11. **Georgy E (2011):** Lumbar repositioning accuracy as a measure of proprioception in patients with back dysfunction and healthy controls. Asian Spine J., 5 (4): 201-7.
12. **Romero-Franco N, Oliva-Pascual-Vaca Á, Fernández-Domínguez J (2023):** Concurrent validity and reliability of a smartphone-based application for the head repositioning and cervical range of motion. Biomedical Engineering / Biomedizinische Technik , 68 (2): 125-132.
13. **Reddy R, Alahmari K, Samuel P *et al.* (2021):** Intra-rater and inter-rater reliability of neutral and target lumbar positioning tests in subjects with and without non-specific lower back pain. J Back Musculoskelet Rehabil., 34 (2): 289-299.
14. **Kaur V, Makhija M, Phadke V (2023):** Reliability and Concurrent Validity of Smartphone Clinometer Application for Measuring Scapular Rotations in Subjects with and Without Shoulder Pain. J Sport Rehabil., 32 (8): 926-931.
15. **Ganokroj P, Sompornpanich N, Kerdsomnuek P *et al.* (2021):** Validity and reliability of smartphone applications for measurement of hip rotation, compared with three-dimensional motion analysis. BMC Musculoskelet Disord., 22 (1): 166. doi: 10.1186/s12891-021-03995-2.
16. **Werner B, Holzgrefe R, Griffin J *et al.* (2014):** Validation of an innovative method of shoulder range-of-motion measurement using a smartphone clinometer application. J Shoulder Elbow Surg., 23 (11): 275-82.
17. **Smith A (2016):** Validation of a smartphone application for measuring shoulder internal rotation and external rotation range of motion with intra-rater reliability. Journal of Sports Medicine and Allied Health Sciences, 2(1): 11. doi:10.25035/jsmahs.02.01.11.
18. **Mohammad W, Elattar F, Elsais W *et al.* (2021):** Validity and Reliability of a Smartphone and Digital Inclinometer in Measuring the Lower Extremity Joints Range of Motion. Montenegrin Journal of Sports Science & Medicine, 10 (2): 47-52.
19. **Miley E, May J, Albertin E *et al.* (2019):** Reliability and Validity for Measuring Active Hip Rotation with the Clinometer Smartphone Application™. Journal of Rehabilitation Sciences & Research, 6 (4): 193-199.
20. **Cox R, Martinez R, Baker R *et al.* (2018):** Validity of a Smartphone Application for Measuring Ankle Plantar Flexion. J Sport Rehabil., 27 (3): 1-3.
21. **Monreal C, Luinstra L, Larkins L *et al.* (2020):** Validity and Intrarater Reliability Using a Smartphone Clinometer Application to Measure Active Cervical Range of Motion Including Rotation Measurements in Supine. J Sport Rehabil., 30 (4): 680-684.
22. **Hwang D, Lee J, Moon S *et al.* (2017):** The reliability of the nonradiologic measures of thoracic spine rotation in healthy adults. Physical Therapy Rehabilitation Science, 6 (2): 65-70.
23. **Ullucci P, Tudini F, Moran M (2019):** Reliability of Smartphone Inclinometry to Measure Upper Cervical Range of Motion. J Sport Rehabil., 28 (1): 1-12.