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Intra-Rater Test-Retest Reliability of Ely's Test Using Smartphone in Patients With Lumbar Extension-Rotation Syndrome

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Abstract

Ely's test is commonly used to assess rectus femoris muscle flexibility. however, a reliability limit of this test was demonstrated by a previous study. In this study, we present an alternative method using an application for a digital horizontal level in a smartphone (DHLS) to complement the reliability limit of Ely's test. The aim of this study was to examine the reliability of Ely's test using DHLS on the pelvis, compared to using visual observation (VO) of pelvic and hip motions. Nineteen patients with lumbar extension-rotation syndrome were recruited for this study. An examiner examined the rectus femoris flexibility (both pass/fail and goniometer scoring) through Ely's test using both DHLS and VO. A retest session was completed two hours later for within-day reliability and seven days later for between-day intra-rater test-retest reliability. Results showed higher Kappa values for pass/fail scoring and higher intraclass correlation coefficient values for goniometer scoring in Ely's test using DHLS, compared to using VO. Measurement error and Bland and Altman plots further demonstrated the degree of intra-rater variance during Ely's test using DHLS in a clinical setting, compared to using VO. These results demonstrated that Ely's test using DHLS showed acceptable reliability compared to using VO. Ely's test using DHLS could be widely used for measuring the rectus femoris muscle flexibility in patients with lumbar extension-rotation syndrome, although the inter-rater reliability needs to be established first.

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Key Words: Digital horizontal level; Ely's test; Reliability; Smartphone.

Introduction

Ely's test is commonly performed by clinicians to examine the flexibility of the rectus femoris muscle in clinical rehabilitation (Peeler and Anderson, 2008). The face validity of Ely's test is confirmed by prominent textbook on orthopedic physical measurement, as is its usefulness as an assessment tool regarding the thigh region (Magee, 2005). Ely's test, which was proposed by Magee (2005), is performed passively by an examiner. If the anterior pelvic tilt or hip flexion occurs during passive prone knee flexion by an examiner, this can indicate that the rectus femoris is tight (Magee, 2005). However, a recent study demonstrated the reliability limits of the knee's active range of motion (ROM) using Ely's test to quantify the rectus femoris flexibility (Peeler and Anderson, 2008). The subjects in the previous study were instructed to maintain a neutral pelvic posture and contact the anterior aspect of the hip on the table without any motions of the hip and pelvis while performing active prone knee flexion (Peeler and

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Anderson, 2008). Whenever the subjects performed the Ely's test, they found difficulty in performing a regular amount of neutral pelvic and hip position by themselves in each session, indicating the reliability limit identified in the previous study (Peeler and Anderson, 2008). Additionally, different results were obtained because the time to stop the passive knee flexion by an examiner was ambiguous during Ely's test when using subjective visual observation (VO) (Peeler and Anderson, 2008).

To develop the reliability of Ely's test, Peeler and Anderson (2008) pointed out the need for an alternative method in further studies. Therefore, our study would use an application for a digital horizontal level in a smartphone (DHLS) on the pelvis as an alternative method. Smartphones and applications are popular among clinicians and can be easily used for assessment of the ROM of shoulder and knee joints (Rosser and Eccleston, 2011; Shin et al, 2012). Smartphones are equipped with a gyro-sensor, which enables the user to determine the levelness of a surface (Shin et al, 2012). The DHLS application shows users the real-time tilt angle of a surface by the inclinometric function, thus making it possible to help in detecting the onset of pelvic movements objectively during Ely's test.

An overly tight rectus femoris muscle can have an influence on low back pain (LBP) and cause alterations in an individual's movement strategy (Lénárt and Kullmann, 1974; Norris, 1995). Among the five subcategories of LBP identified by Sharmann (2002), lumbar extension rotation syndrome is most common in the clinical setting and characterized biomechanically by increased stiffness of the rectus femoris, which induces LBP during active prone knee flexion (Park et al, 2011; Sahrmann, 2002; Scholtes et al, 2009). For patients with lumbar extension-rotation syndrome, clinicians should assess the flexibility of the rectus femoris muscle (Park et al, 2011; Sahrmann, 2002).

No studies have investigated the assessment of rectus femoris flexibility and joint ROM using real-time investigation of pelvic motions using DHLS in individuals with lumbar extension - rotation syndrome. The purpose of this investigation was to test the hypothesis that the Ely's test using DHLS provides more acceptable reliability of rectus femoris muscle flexibility and joint ROM than Ely's test using VO of pelvic and hip movements. Specifically, the study had the following aim: to compare the within- and between-day intra-rater test-retest reliability of the Ely's test between using DHLS and VO.

Methods

Subjects

Following the method proposed by Walter et al. (1998), we decided that a minimal sample size would be 18 subjects who were required to test whether a gained reliability of .90 exceeded at least the acceptable reliability of .70 assuming a power of 80% and an α level of .05. For this study, 19 men (40.2±3.17 years) with lumbar extension-rotation syndrome were recruited from 28 subjects diagnosed with work-related mechanical chronic LBP at work-conditioning centers in Korea (Figure 1). We defined chronic LBP as LBP exceeding seven weeks (Van Dillen et al, 1998). The average LBP intensity of our patients while performing activities of daily living before entry to this study was above 60 ㎜ on a visual analogue scale (VAS), ranging from 0 to 100 ㎜ (Maluf et al, 2000). The subjects were selected from workers participating in a work-conditioning program at their workplace. Nine subjects were ruled out from our study because they did not exhibit lumbar-extension rotation syndrome or had acute LBP. The exclusion criteria included specific LBP with radiating symptom, hip and knee joint contractures, and past or present neurological or cardiopulmonary diseases.

To classify the lumbar extension-rotation syndrome, we used the evaluation methodology proposed

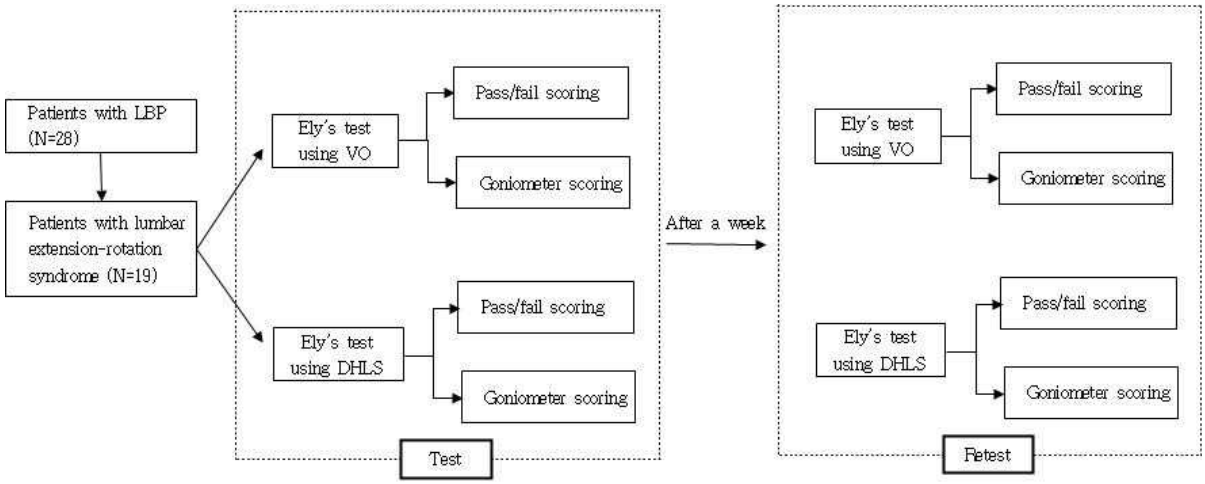

Figure 1. Flow chart of experimental procedure.

by Sahrmann (2002) and Maluf et al (2000). This classification method consists of alignment and movement tests. The principal investigator performed classification using criteria proposed by Sahrmann (2002). In the initial primary test, the subject assumed a position or performed a movement. When the subject provoked LBP symptoms in the primary test, the secondary test was performed with a modified position or movement pattern that decreased lumbar extension-rotation, resulting in reduced LBP symptoms (Van Dillen et al, 1998). Several tests were used to classify the syndrome and we defined lumbar extension-rotation syndrome when the results of all tests met the criteria suggested by Van Dillen et al (1998). The detailed procedures of several tests to determine the diagnosis of lumbar extension-rotation syndrome have been described in a previous study (Norton et al, 2004). The reliability of examination and classification were established in a previous study (Van Dillen et al, 1998). The subject characteristics are presented in Table 1. Before this study, the principal investigator explained all of the procedures to the subjects in detail and all subjects signed an informed consent form.

Instruments

Application for DHLS

To determine whether the pelvic and hip movements occur, we used DHLS application (Spirit Level Pro free version, Androinica, Germany) in a smartphone[1)] instead of using VO of pelvic and hip movements by the examiner in Magee's method (Figure 2A). DHLS can determine the levelness of a surface

Table 1. General characteristics (N=19)

Characteristics	Mean±SD[c]
Age (yrs)	40.2±3.2
Height (㎝)	173.2±4.4
Body mass (㎏)	71.8±5.2
VAS[a] (㎜)	62.5±2.0
Duration of LBP[b] (yrs)	1.3±.4
Modified Oswestry Disability Index (%)	13.4±6.2

[a]visual analogue scale, [b]low back pain, [c]mean±standard deviation.

1) Gallexy II, Samsung Electronics, Suwon-si, Gyeonggi-do, Korea.

Figure 2A. Digital horizontal level in a smartphone (DHLS) on pelvis.

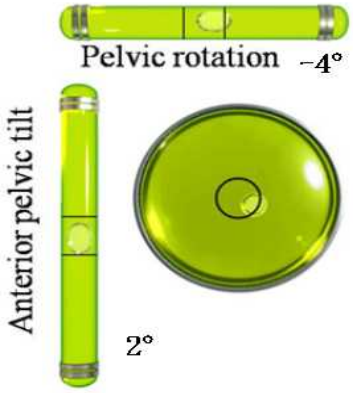

Figure 2B. Monitor of digital horizontal level in a smartphone (DHLS) when pelvic movements occurred.

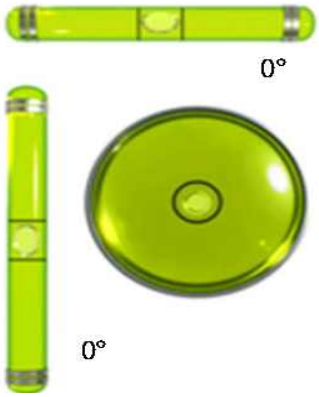

Figure 2C. Monitor of digital horizontal level in a smartphone (DHLS) when no pelvic movements occurred.

using a gyro-sensor. Additionally, inclinometer function of DHLS can calculate the leaning angle of x- and y- axis automatically. When anterior pelvic tilt occurred during passive prone knee flexion, the bubble in the y-axis of the DHLS started to move, representing the value of leaning angle. When pelvic rotation occurred during passive prone knee flexion, the bubble in the x-axis of the DHLS started to move, representing the value of leaning angle (Figure 2B). No movement of the two bubbles means that the relaxed pelvic position is being maintained (Figure 2C). A bubble in circle of the center of DHLS monitor represent the concurrent view of pelvic movements in both x- and y- axis (Figure 2B) (Figure 2C).

Goniometer

To quantify the rectus femrois muscle flexibility, we measured range of knee flexion using goniometer while performing Ely's test. Knee flexion ROM was assessed using a double-arm goniometer, with 180 degrees marked in one-degree increments, which is a widely used device in the clinical setting (Rothstein et al, 1993).

Procedures

Assessment took place in a work-conditioning center located in Korea. An examiner in this study had six years experience of assessment and treatment in musculoskeletal disorders and often uses the Ely's test for evaluating patients with LBP. All participants were instructed to wear short pants for assessment. Assessment by an examiner took two sessions. The interval duration between the initial test and retest for between-day reliability was a week at the same time of the day, and for within-day reliability, the interval duration was two hours. Before participating in this study, all subjects were asked to avoid partaking of severe exercise during the seven days of participating in this study (Peeler and Anderson, 2008) (Figure 1).

An examiner assessed rectus femoris muscle flexibility and knee joint ROM using Ely's test. Ely's test determines the rectus femoris muscle flexibility according to whether the pelvic and hip movements occur or not during passive prone knee flexion (Magee, 2005). To determine whether the pelvic and hip movements occur, we used DHLS application instead of using VO of pelvic and hip movements by the examiner in Magee's method (Magee, 2005). Subjects assumed a prone position on the treatment table with a resting position of pelvis and hip joint. To decide which leg to assess, the examiner passively flexed the bilateral knee joints of the subject. When performing passive prone knee flexion, subjects were asked to express the intensity of LBP using a VAS. We assessed the side of the leg that had greater VAS during active prone knee flexion of

both sides. The examiner placed a smartphone on the middle of the subject's sacrum and fastened it using a band with the smartphone case (Figure 2A). Before starting the Ely's test for assessing pass/fail and knee joint ROM, we determined the resting prone position of the pelvis as a neutral position subjectively and calibrated the DHLS to zero point at the starting position of each session. When the examiner wrote the pass/fail and goniometer scores for between-day reliability, tester was blind to previous test scores before a week.

A. Pass/fail scoring

The examiner decided pass/fail using DHLS according to Magee's method (Magee, 2005). The examiner performed passive knee flexion several times until he or she was able to maintain the relaxed position of the lumbopelvic region and lower extremities. To determine pass or fail scoring, the examiner passively flexed one knee and brought the subject's heel towards his buttocks while there was no movement of the bubble of the x- and y- axis on the digital horizontal level. No movement of the two bubbles means the initial relaxed pelvic position is being maintained, as is the contact of the anterior aspect of the hip with the bottom of the treatment table, giving the score of a pass. If either the x- or y- axis of the bubble moved during passive prone knee flexion, this meant that anterior pelvic tilt or pelvic rotation had occurred and the hip on the same side was flexed spontaneously, giving the score of a fail.

B. Goniometer scoring

Knee joint ROM was assessed using a goniometer. Before assessing knee joint ROM, we attached adhesive markers on the greater trochanter of the femur, head of the fibula, and lateral malleolus of the ankle to minimize measurement error (France and Nester, 2001). Subjects were instructed to maintain a relaxed position of the pelvis, hip and knee joint. The examiner passively flexed the test knee and brought the subject's heel towards the buttocks. At the same time, the examiner observed whether digital horizontal level on the pelvis was in the neutral position through observing the value of the x- and y-axis on DHLS. Criterion of pelvic movement onset is above one degree during prone knee flexion (Gombatto et al, 2006). If either value of the x- or y- axis was one degree, the examiner stopped passive prone knee flexion and measured knee flexion ROM using the goniometer. ROM of passive knee flexion was measured between one axis (line from the greater trochanter of the femur to the head of the fibula), and the other axis (from the head of the fibula to the lateral malleolus of the ankle) (Peeler and Anderson, 2008).

To examine the pass/fail and goniometer score using VO of Ely's test, all procedures were the same except for the use of the DHLS. To give the pass or fail score for rectus femoris flexibility, the examiner observed spontaneous hip flexion using VO during passive knee flexion. To examine the goniometer score, the examiner assessed knee joint ROM when spontaneous hip flexion and pelvic motion occurred. We examined the two methods (DHLS and VO) randomly.

Statistical Analysis

All statistical analysis were performed using SPSS ver. 12.0 software. To evaluate within- and between-day intra-rater test-retest reliability of knee joint ROM, we used an intraclass correlation coefficient (ICC [3,1]) model. To determine the within- and between-day intra-rater reliability of rectus femoris flexibility (pass/fail scoring), we used a corrected Kappa statistic. According to previous studies, ICC and Kappa values above .75 are considered high levels of reliability, while ICC and Kappa values between .4 and .75 indicate fair-to-moderate levels of reliability. ICC values below .4 indicate a poor level of reliability (Atkinson and Nevill, 1998; Haley and Osberg, 1989). Additionally, three statistical forms of measurement error (standard error of measurement

[SEM=SD $\sqrt{(1-ICC)}$], method error [ME= $SD^2/\sqrt{2}$] and coefficient of variation [CV= $(ME/Mean)\times 100$]) were used for examining the within-subject variation. Minimum difference (MD= $SEM\times 1.96\times \sqrt{2}$) was calculated to presume a "real" difference exists between the test/retest scores of an examiner for the Ely's test (Peeler and Anderson, 2008). Finally, Bland and Altman graphs with accompanying 95% limits of agreement provide a visual description of the range of goniometeric scoring between test and retest for each subject (Bland and Altman, 2007).

Results

The mean knee joint ROMs for all subjects were 89.0±1.80 degrees when performing Ely's test using DHLS and 102.9±4.07 degrees when performing Ely's test using VO. Corrected Kappa values for pass/fail scoring and ICC values for goniometer scoring of both within-day and between-day intra-rater reliability were on average higher for when the examiner performed Ely's test using DHLS compared to using VO (Table 2). Lesser values of SEM, CV, ME, and MD of goniometer scoring appeared when using DHLS, compared to using VO (Table 3). Bland and Altman plots (with accompanying 95% limits of agreement) represent lesser difference of the goniometer scoring over the test-retest sessions in within-day and between-day reliability when using DHLS, compared to VO (Figure 3).

Discussion

Previous studies demonstrated the reliability limit of Ely's test, which is commonly used to assess rectus femoris muscle flexibility, suggesting that further study is necessary (Peeler and Anderson, 2008). We provided Ely's test using DHLS as an alternative method to standardize and quantify the amount of pelvic motions during Ely's test, resulting in higher within- and between-day intra-rater reliability than using VO. This is the first study to examine the intra-rater reliability of assessment of rectus femoris muscle flexibility through Ely's test using DHLS in patients with lumbar extension-rotation syndrome. The results of this study support the hypothesis that Ely's test using DHLS provides more acceptable reliability of rectus femoris muscle flexibility and joint ROM than Ely's test using VO.

In this study, we found that within- and between-day intra-rater reliability of Ely's test using DHLS was superior, compared to the data of Ely's test using VO (Table 2). A previous study suggested

Table 2. Ely's test corrected kappa statistics for pass/fail scoring, and ICC (3,1) values for goniometer scoring

Intra-rater reliability	Pass/fail scoring		Goniometer scoring	
	VO[a]	DHLS[b]	VO	DHLS
Within-day	.64*	.99*	.75*	.92*
Between-day	.64*	.99*	.65*	.87*

[a]visual observation, [b]digital horizontal level in a smartphone, *p<.05.

Table 3. Measurement error and minimum difference values for goniometer scoring

Intra-rater reliability	CV%		ME°		SEM°		MD°	
	VO[a]	DHLS[b]	VO	DHLS	VO	DHLS	VO	DHLS
Within-day	3.78	2.07	10.54	2.39	1.93	.52	5.35	1.44
Between-day	4.13	1.98	12.98	2.19	2.53	.64	7.03	1.76

[a]visual observation, [b]digital horizontal level in a smartphone.

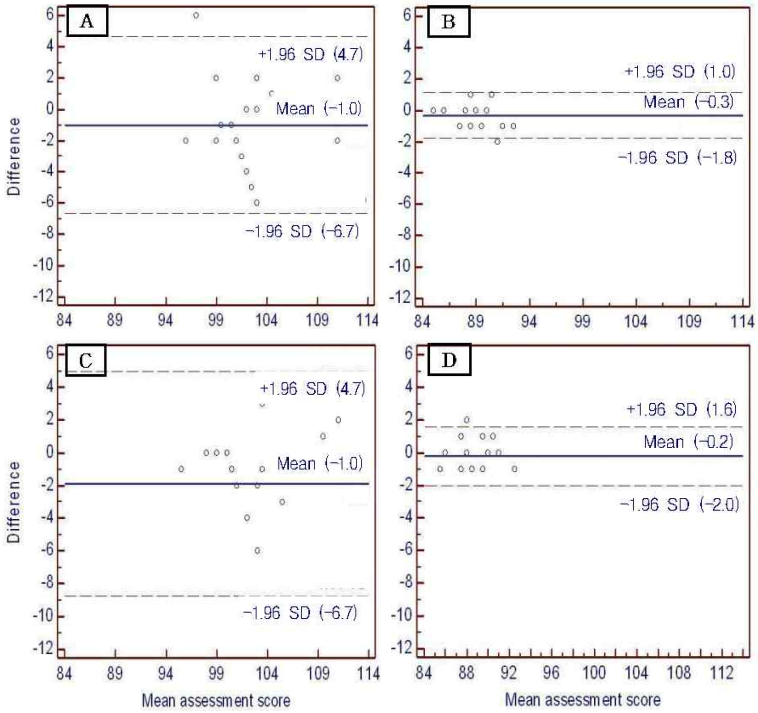

Figure 3. Bland and Altman plots (measured in degrees) representing differences in goniometer scoring in within-day using visual observation (VO) and digital horizontal level in a smartphone (DHLS) and in between-day using VO and DHLS against mean scores for each subject (A: Within day using VO, B: Within day using DHLS, C: between-day using VO, D: between-day using DHLS).

that VO of pelvic and hip motions was one of the confounding variables related to the reliability limits of Ely's test (Peeler and Anderson, 2008). When performing Ely's test using VO, it is difficult for an examiner to decide whether pelvic and hip movements occurred consistently during within or between days. High ICC values of reliability when using DHLS mean that by using DHLS on the pelvis, it is possible to determine whether pelvic movements occurred consistently during within or between days. Because the examiner observed the movement onset of the pelvis through monitoring the DHLS during passive knee flexion, the examiner could detect when anterior pelvic tilt or pelvic rotation were above one degree and stopped passive knee flexion to record knee joint ROM. The DHLS application may provide a more reliable method than the examiner's eye (VO) for giving a criteria related to the stopped time of passive knee flexion. Objective assessment by DHLS during Ely's test may have an influence on more reliable results related to rectus femoris muscle flexibility than using VO.

We found higher Kappa values for Ely's test using DHLS than VO. Although it is characteristic for patients with lumbar extension-rotation syndrome to experience a greater amount of anterior pelvic tilt and pelvic rotation by prone knee flexion (Park et al, 2011; Sahrmann, 2002), two subjects in this study showed minimal movements of pelvis, which were difficult to detect visually during passive knee flexion. If the amount of pelvic motion was too small to detect by the examiner's eye during prone knee flexion for Ely's test, the examiner had difficulty to decide pass/fail scoring, resulting in lesser Kappa values when using VO.

When comparing the Kappa value (.52) of a previous study (Peeler and Anderson, 2008), the Kappa values of DHLS and VO (.99 and .64, respectively)

in this study were higher. The subjects of a previous study were healthy and could flex the knee joint at about 120 degrees, which indicates sufficient rectus femoris muscle flexibility and minimal pelvic motions, making it difficult for the examiner to decide pass/fail scoring. Subjects in this study with lumbar extension-rotation syndrome have a characteristic of less flexibility of the rectus femoris muscle and greater anterior pelvic tilt and pelvic rotation during prone knee flexion than healthy subjects (Park et al, 2011), resulting in a high level of reliability for both DHLS and VO.

When performing Ely's test using DHLS, measurement errors (SEM, ME, and CV) for goniometer scoring were less than when using VO. Because DHLS gives more consistent criteria for when the limit of knee flexion was stopped than VO, measurement error is diminished. The lesser value of SEM resulted in a lower MD when using DHLS than using VO. The SEM values indicate that the MD required to assume that a "real" difference exists between test/retest scores of an examiner for the Ely's test was approximately from 1.4 to 1.7 degrees when using DHLS, compared to using VO (MD range from 5.3 to 7.0). This suggests valuable information for developing the clinical reliability limits of the Ely's test and enabling clinicians to be able to make a decision related to whether "real" change of rectus femoris flexibility between testing sessions has occurred, or whether the change is just a result of measurement error.

The mean knee joint ROM when using DHLS (89.0±1.80 degrees) was less than using VO (102.9±4.07 degrees) because DHLS prevents overestimation of the amount of rectus femoris flexibility (knee joint ROM). According to the results of the pilot study, DHLS detects the onset of pelvic motions earlier than VO. Earlier detection of the timing of pelvic movements when using DHLS results in a lesser value of knee ROM than using VO.

This study has some limitations. First, these results cannot be generalized to women with lumbar extension-rotation syndrome, because we recruited only men with lumbar extension-rotation syndrome. Second, we did not examine the inter-rater reliability of Ely's test using DHLS, although measurement of inter-rater reliability may be equally as important in the clinical setting. Further studies are required to compare the within- and between-day inter-rater reliability using between DHLS and VO for Ely's test in patients with lumbar extension-rotation syndrome. Also, some factors would be influenced on Ely's test reliability, such as an examiner assessment skill, other kinds of application related digital horizontal level and the performance of gyro-sensor in other kinds of smartphone, thus, these factors should be considered by tester before performing Ely's test.

Conclusion

The study demonstrated that within- and between-day intra-rater test-retest reliability for Ely's test using DHLS was superior to the results of using VO in patients with lumbar extension-rotation syndrome. Based on the results of this study, we recommend the use of the DHLS by an examiner to measure rectus femoris muscle flexibility for Ely's test in the clinical setting.

References

Atkinson G, Nevill AM. Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. Sports Med. 1998;26(4):217-238.

Bland JM, Altman DG. Agreement between methods of measurement with multiple observations per individual. J Biopharm Stat. 2007;17(4):571-582.

France L, Nester C. Effect of errors in the identification of anatomical landmarks on the accuracy of Q angle values. Clin Biomech (Bristol, Avon). 2001;16(8):710-713.

Gombatto SP, Collins DR, Sahrmann SA, et al. Gender differences in pattern of hip and lumbo-pelvic rotation in people with low back pain. Clin Biomech (Bristol, Avon). 2006;21(3):263-271.

Haley SM, Osberg JS. Kappa coefficient calculation using multiple ratings per subject: A special communication. Phys Ther. 1989;69(11):970-974.

Harris-Hayes M, Van Dillen LR, Sahrmann SA. Classification, treatment and outcomes of a patient with lumbar extension syndrome. Physiother Theory Pract. 2005;21(3):181-196

Lénárt G, Kullmann L. Isolated contracture of the rectus femoris muscle. Clin Orthop (Relat Res). 1974;99:125-130.

Magee DJ. Orthopedic Physical Assessment. Philadelphia WB, Saunders, 2005:693.

Maluf KS, Sahrmann SA, Van Dillen LR. Use of a classification system to guide nonsurgical management of a patient with chronic low back pain. Phys Ther. 2000;80(11):1097-1111.

Norris CM. Spinal stabilisation 4: Muscle imbalance and the low back. Physiotherapy. 1995;81(3):127-138.

Norton BJ, Sahrmann SA, Van Dillen FL. Differences in measurements of lumbar curvature related to gender and low back pain. J Orthop Sports Phys Ther. 2004;34(9):524-534.

Park KN, Cynn HS, Kwon OY, et al. Effects of the abdominal drawing-in maneuver on muscle activity, pelvic motions, and knee flexion during active prone knee flexion in patients with lumbar extension rotation syndrome. Arch Phys Med Rehabil. 2011;92(9):1477-1483.

Peeler J, Anderson JE. Reliability of the Ely's test for assessing rectus femoris muscle flexibility and joint range of motion. J Orthop Res. 2008;26(6):793-799.

Sahrmann SA. Diagnosis and Treatment of Movement Impairment Syndrome. St Louis, Mosby, 2002:103-111.

Scholtes SA, Gombatto SP, Van Dillen LR. Differences in lumbopelvic motion between people with and people without low back pain during two lower limb movement tests. Clin Biomech (Bristol, Avon). 2009;24(1):7-12.

Richardson CA, Jull GA. Muscle control-pain control. What exercises would you prescribe? Man Ther. 1995;1(1):2-10.

Rothstein JM, Miller PJ, Roettger RF. Goniometric reliability in a clinical setting: Elbow and knee measurements. Phys Ther. 1983;63(10):1611-1615.

Rosser BA, Eccleston C. Smartphone applications for pain management. J Telemed Telecare. 2011;17(6):308-312.

Shin SH, Ro du H, Lee OS, et al. Within-day reliability of shoulder range of motion measurement with a smartphone. Man Ther. 2012;17(4):298-304.

Van Dillen LR, Sahrmann SA, Norton BJ, et al. Reliability of physical examination items used for classification of patients with low back pain. Phys Ther. 1998;78(9):979-988.

Walter SD, Eliasziw M, Donner A. Sample size and optimal designs for reliability studies. Stat Med. 1998;17(1):101-110.

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