

Reliability of Measured Popliteal Angle by Traditional and Stabilized Active-Knee-Extension Test

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Abstract

The active-knee-extension (AKE) test has been used to measure hamstring muscle length. The traditional AKE test measures the popliteal angle to the point of resistance with a 90-degree flexion of the hip fixed by straps, while the stabilized AKE test measures the popliteal angle to the point of resistance with a 90-degree flexion of the hip stabilized using a pressure biofeedback unit providing lumbopelvic stabilization. The purpose of this study was to determine test-retest reliability of the traditional AKE test and stabilized AKE test. Twenty healthy adults participated in the study. The popliteal angles were measured with a digital inclinometer during each test. To assess the test-retest reliability between the 2 test sessions, intraclass correlation coefficients (ICCs) were calculated. The intrasubject coefficient of variation (CV_{intra}) was also calculated. To compare the traditional and stabilized AKE tests for changes in pressure, paired t-tests were applied. The results of this study were as follows: 1) ICCs(3,1) value for test-retest reliability was .96 in the traditional AKE test, and was .98 in the stabilized AKE test. 2) The maximal CV_{intra} was 33.7% in the traditional AKE test and 15.7% in the stabilized AKE test. 3) Differences of 6.1 ± 2.1 mmHg in pressure were measured in the traditional AKE test, and differences of 1.2 ± 1.0 mmHg in pressure were measured in the stabilized AKE test. The results show the traditional and stabilized AKE test to be highly reliable, with test-retest reliability. However, the stabilized AKE test represented less variation and more stabilization than the traditional AKE test. Further study is needed to measure the inter-rater reliability of the stabilized AKE test for generalization and clinical application.

Key Words: Active-knee-extension test; Hamstring length; Lumbopelvic stabilization; Test-retest reliability.

I . Introduction

Hamstring length and stiffness were examined commonly in a clinical environment. Structural and functional changes of hamstring muscles in neuromuscular and musculoskeletal disorders affect the range of motion (ROM) of the lower extremities, as well as gait and posture (Buurke et al, 2004; Li et al, 1996). The hamstring length test as physical ex-

amination is important in the assessment of an initial diagnosis, to evaluate structural and functional improvements, and to report the effect of physical therapy (Ekstrand et al, 1982).

Tests for measuring hamstring length have been reported in a number of publications, along with variations of the test suggested by physical examiners (Kendall et al, 2005; Kuo et al, 1997; Li et al, 1996). Variations of the hamstring length test include the

straight-leg-raising (SLR) test (Cameron et al, 1994), toe-touch (TT) test (Bennell et al, 1999), sit-and-reach (SAR) test (James, 2008), knee-extension-angle (KEA) test (White et al, 2009), and active-knee-extension (AKE) test (Gajdosik and Lusin, 1983). Although these tests have been used by clinicians in various clinical settings, limitations of each hamstring length test have been observed. To accurately measure hamstring muscle length, the test must provide lumbopelvic stabilization (Kendall et al, 2005). However, these testing methods rarely control lumbopelvic movement (Bohannon et al, 1985; Kippers and Parker, 1987).

Some researchers have suggested that spine and pelvis control were well designed in the AKE test (Gajdosik and Lusin, 1983; Rakos et al, 2001). The traditional AKE test is performed in the supine position with hip and knee flexion at 90 degrees of the test leg with the contralateral leg extended (Gajdosik and Lusin, 1983). The contralateral leg is stabilized by an elastic strap on the examination bed. Clinically, the hamstring length is measured at the point at which subjects feel strong resistance but could tolerate resistance in the stretched hamstring muscle. The AKE method used in these procedures were reported to have test-retest reliability coefficients of .99 (Gajdosik and Lusin, 1983) and inter-rater reliability coefficients of .79 (Rakos et al, 2001). Kane and Bernasconi (1992) reported that pelvic rotation can be effectively controlled during an AKE test, and that the test can be used as an accurate measurement tool to evaluate hamstring length. However, there is no evidence that the pelvic rotation was well controlled.

In more recent studies, a pressure biofeedback unit has been used to monitor the motion of lumbopelvic region (Cynn et al, 2006; von Garnier et al, 2009). A pressure biofeedback unit provides the benefit of monitoring lumbopelvic stabilization by active contraction of deep abdominal muscles (Richardson and Jull, 1995). This stabilized AKE test, which is a modified version of the traditional AKE test, uses the pressure biofeedback unit for preventing lumbopelvic motion during AKE test. Pelvic rotation and lumbar

flattening which occurs during the AKE test are controlled not by an external device (elastic strap), but by an internal stabilizing system (isometric abdominal muscle contraction) (Tesh et al, 1987).

No published studies examining the test-retest reliability of the stabilized AKE test have been found. Therefore, the purpose of this study was to establish test-retest reliability for the stabilized AKE test. Our hypothesis was that the stabilized AKE test could be accepted as the more reliable measurement of hamstring length.

Methods

Subjects

Twenty subjects were recruited (N=20; 11 females and 9 males) for this study. Initially, 21 subjects were recruited to participate however, 1 subject was excluded based on difficulty in maintaining voluntary abdominal contractions. All subjects were free of musculoskeletal injury and neurologic deficits in the lumbar and lower extremities for 1 year. All data were collected by 2 physical therapists for 2 days. The mean age, height, and weight of the subjects are summarized in Table 1.

Traditional AKE Test

Each subject was placed in the supine position on an examination bed with hip and knee extension of both lower extremities. A pressure biofeedback unit was placed under the lumbopelvic region, and the contralateral leg was fixed to the bed with strap across the thigh. The test leg was flexed 90 degrees of both the hip and knee on an adjustable support table the angle was confirmed with a universal

Table 1. General characteristics of subjects (N=20)

Characteristics	Mean±SD
Age (yrs)	23.5±2.8
Height (cm)	168.3±8.9
Weight (kg)	59.6±11.9

goniometer. In this position, the plastic bag was inflated to a pressure of 40 mmHg (initial point); however, subjects were not concerned about the pressure biofeedback unit. With the measured hip maintained at 90 degrees flexion and the ankle relaxed, the subjects were instructed to actively extend the knee. Active knee extension was performed until subjects feel tolerate resistance in the stretched hamstring muscle. At this point, terminal point, the traditional AKE test was used to measure the popliteal angle by implementing the attached digital inclinometer. At the same time, the changes in pressure between initial and terminal point were recorded by the examiner. The popliteal angle is defined as the angle of knee flexion angle to point of resistance when the hip is flexed at 90 degrees and the knee is extended (Katz et al, 1992) (Figure 1).

Stabilized AKE Test

The stabilized AKE test reinforced lumbopelvic stabilization by using a pressure biofeedback unit. Each subject was placed in the supine position, and a pressure biofeedback unit was placed between the examination bed and the subject's lumbopelvic region (L3~L5, S1). Then, the measured lower extremity was flexed 90 degrees of the hip and knee on an adjustable support table. In this position, the plastic bag was inflated to a pressure of 40 mmHg. The subject's abdominal contractions and lumbopelvic movements were monitored by maintaining 60 to 70 mmHg in pressure (initial point) during the AKE test (von Garnier et al, 2009). The appropriate pressure used on each subject was determined through preliminary examination to be between 60 and 70 mmHg when a subject performed deep abdominal contractions. During deep abdominal contractions, active knee extension was performed simultaneously until subjects feel tolerate resistance in the stretched hamstring muscle (terminal point). At this point, the stabilized AKE test was used to measure the popliteal angle by the digital inclinometer. The changes in pressure during the test were recorded by the ex-

aminer while the subject held his or her knee extended position at the end point.

Procedures

We proceeded with our experiment for 2 days to test and retest. On the first test day, the examiner drew a line between each subject's lateral malleolus of the ankle and the fibular head of the dominant leg. The line provided a reference for accurate placement and replacement of a digital inclinometer, which was attached to a thin, narrow metal bar placed on the reference line. Then, the subject lay in the supine position on an examination bed, arms to each side. A pressure biofeedback unit was placed under the lumbopelvic region. Both the traditional and stabilized AKE tests were performed the order in which the tests were performed was randomly assigned to prevent any test order effect. A 5-min rest period between tests for each subject was provided to avoid carry over effect. On the second test day, the same procedures were performed. The subjects were not provided any information about their performance re-

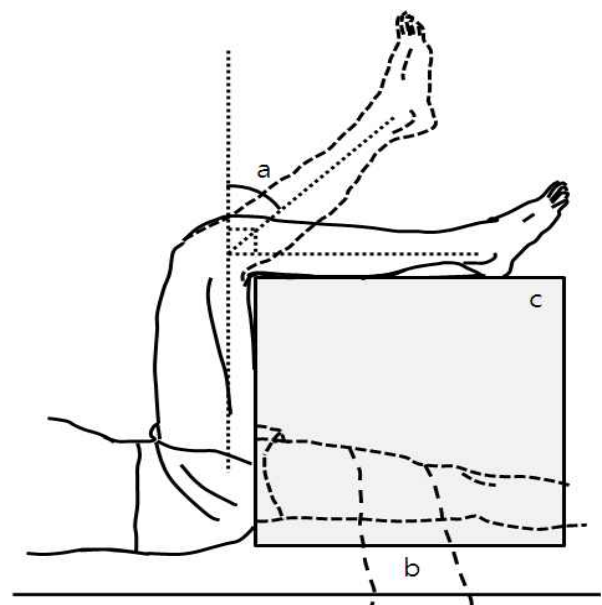


Figure 1. Experimental setting and starting position for testing (a: popliteal angle, b: stabilizing strap, c: adjustable support table).

sults until subject's tests were completed on the second test day.

Statistical Analysis

Descriptive statistics were performed for all variables measured. To assess the test-retest reliability between the 2 test sessions, intraclass correlation coefficients [ICCs(3,1)] were calculated. Also, the intrasubject coefficient of variation (CV_{intra}) was calculated. Additionally, to compare the traditional and stabilized AKE tests for changes in pressure, paired t-tests were applied. The statistical significance level α was set at .05.

Results

The test-retest reliability of the popliteal angle in the traditional and stabilized AKE tests are shown in Table 2. Good reliability was shown for all measurements traditional AKE [ICCs(3,1)=.96; 95% confidence interval (CI)=.89~.98; $p<.01$], and stabilized AKE [ICCs(3,1)=.98; 95% CI=.95~.99; $p<.01$].

The CV_{intra} of both the first and second tests is represented in Table 3. In the traditional AKE test, the range of CV_{intra} was 3.8~33.7% and 50% or more of CV_{intra} values were greater than 10%. In the stabilized AKE test, the range of CV_{intra} was 1.1~15.7% and most of CV_{intra} values were less than 10% (Table 3).

Table 4 shows the changes in the pressure bio-feedback unit during the traditional and stabilized AKE tests. Differences of 6.1 ± 2.1 mmHg in pressure between initial and terminal point were measured in the traditional AKE test, and differences of 1.2 ± 1.0 mmHg in pressure between initial and terminal point

were measured in the stabilized AKE test. There measurements show a significant increase in pressure in the traditional AKE test compared to the stabilized AKE test ($p<.01$).

Discussion

The purpose of this study was to establish test-retest reliability for the traditional and stabilized AKE tests. Although various methods for assessing hamstring length are used by clinicians, these methods do not adequately confirm hamstring muscle length (Gajdosik and Lusin, 1983; Rakos et al, 2001). The critical problem with attaining accurate measurements of hamstring length is the need for appropriate and adequate lumbopelvic stabilization. In many hamstring length tests, lumbopelvic stabilization is not provided because the muscle tension induces pelvic rotation during muscle lengthening (Bohannon, 1982).

Gajdosik and Lusin (1983) presented a traditional AKE test that could produce more valid hamstring length measurements, emphasizing that the method is an objective and reliable tool for measuring hamstring muscle length based on strict body stabilization. The body stabilization procedure they utilized during the AKE test consisted of stabilizing the thigh at a 90-degree flexion of the hip, and then the isolated active knee extension instructed to not force the thigh during the test (Gajdosik and Lusin, 1983). However, as we know, even a strap and an unilateral hip flexion do not provide full stabilization of the spine and pelvis because when the terminal point of knee extension is reached, a force is delivered to the lumbopelvic region and the pelvic rotation

Table 2. Test-retest reliability of the popliteal angle between the traditional and stabilized AKE tests (N=20)

	Intraclass correlation coefficients (ICCs)				
	Mean \pm SD (degree)		ICCs(3,1)	95% Confidence Interval	p
	1st test	2nd test			
Traditional AKE	30.8 \pm 16.5	33.3 \pm 18.0	.96	.89~.98	<.01
Stabilized AKE	41.9 \pm 15.8	41.7 \pm 14.9	.98	.95~.99	<.01

is induced (Bohannon, 1982).

Recently, to provide lumbopelvic stabilization, a pressure biofeedback unit has been used in assessment, education, and exercises (Smeets, 2009; von Garnier et al, 2009). This device monitors the lumbopelvic stabilization fostered by contraction of deep abdominal muscles (von Garnier et al, 2009). Deep abdominal muscle contractions, especially transversus abdominis, internal obliques, and lumbar multifidus,

achieve lumbopelvic stabilization by producing stiffness that results from increasing intra-abdominal pressure and thoracolumbar fascia (Cynn et al, 2006). von Garnier et al (2009) suggested that providing visual feedback of abdominal muscle contractions may enhance and increase subjects' motivation to exercise.

In this study, for effective and adequate lumbopelvic stabilization, a pressure biofeedback unit was applied to the traditional AKE test, making it a "stabilized" AKE test. The test-retest reliability of the popliteal angle are high in both the traditional AKE test [ICCs(3,1)=.96] and stabilized AKE test [ICCs(3,1)=.98]. Also, the CV_{intra} of the first and second tests was 3.8~33.7% in the traditional AKE test and 1.1~15.7% in the stabilized AKE test. Both tests proved reliable however, the stabilized AKE test represented less variation than the traditional AKE test.

To examine changes in lumbopelvic movement that is, lumbar flattening and pelvic rotation, the amount of variation of pressure was recorded. The variation was 6.1±2.1 mmHg in the traditional AKE test and 1.2±1.0 mmHg in the stabilized AKE test, showing a significant increase in variation in the traditional AKE test compared to the stabilized AKE test. Variations within 2 mmHg in pressure during deep abdominal contractions were considered successful performances (von Garnier et al, 2009). These results show that in the traditional AKE test, lumbopelvic movement was more induced, and in the stabilized AKE test, stabilization of the lumbopelvic region was more provided. That is, the stabilized AKE test represented more stabilization than the traditional AKE test. We considered that the stiffness of the abdominal wall and lumbar spine prevented compensational pelvic motion during ham-

Table 3. Intrasubject coefficient of variation (CV_{intra}) of the test and retest Unit: %

Subject	Traditional AKE	Stabilized AKE
1	17.9	5.2
2	8.3	2.9
3	12.3	2.1
4	4.2	1.2
5	3.8^a	1.1^a
6	11.7	9.3
7	8.8	2.7
8	8.5	6.6
9	15.7	3.6
10	7.1	3.2
11	33.7^b	15.7^b
12	20.2	7.4
13	8.8	6.3
14	12.9	9.4
15	8.8	2.5
16	10.4	2.6
17	31.9	2.4
18	19.4	2.1
19	8.6	1.7
20	12.3	2.7

^aminimal CV_{intra}.

^bmaximal CV_{intra}.

Table 4. Comparisons of the changes measured from the pressure biofeedback unit readings from both the traditional and stabilized AKE test (N=20)

	Mean±SD (mmHg)	t	p
Traditional AKE	6.1±2.1 ^a	8.4	<.01
Stabilized AKE	1.2±1.0		

^aMean±SD of test and retest.

string stretching.

The results show the traditional and stabilized AKE test to be highly reliable. Furthermore, the stabilized AKE test represented less variation and more stabilization than the traditional AKE test. However, it does have limitations, including being restricted to persons with active abdominal contractions and knee extension. Therefore, the test may not be appropriate for some patients with neuromuscular disorders. Also, inter-rater reliability was not examined in this study. So, measurement of inter-rater reliability of the stabilized AKE test for generalization and clinical application warrants further investigation.

Conclusion

The purpose of this study was to compare test-retest reliability between the traditional and stabilized AKE tests. The test-retest reliability of each was high however, the variation of the intrasubject coefficient in the stabilized AKE test was less than in traditional AKE. The mean of changes in pressure during the stabilized AKE test was lower than the mean of those during the traditional AKE test. This difference is considered to be the reason why unwanted lumbopelvic motion was induced in traditional AKE test; the unwanted lumbopelvic motion was indicated by changes of pressure. Therefore, we conclude that although the results show the traditional and stabilized AKE test to be highly reliable, the stabilized AKE test represented less variation and more stabilization than the traditional AKE test.

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- This article was received September 1, 2009, and was accepted October 15, 2009.