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Modifying a Back Endurance Test for Examining Erector Spine Muscles by Adding Lateral Trunk Bending and Trunk Rotation

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| Abstract |

Purpose: Although some studies indicate that the Sorensen test may not be used to examine back muscles such as the erector spinae, alternatives to the back-extension test are rarely suggested. Therefore, the purpose of the present study was to investigate an effective way to stimulate the erector spinae muscles by adding a component of trunk rotation and lateral bending to general back extensions.

Methods: A total of 18 healthy, physically active participants performed simple trunk extension, extension with trunk rotation, and extension with lateral bending. Surface electromyography responses of the latissimus dorsi, thoracic, and lumbar levels of the erector spinae; the gluteus maximus; and the biceps femoris muscles were investigated during these 3 conditions of modified back extension tests.

Results: The simple trunk extension exercise caused significant increases in activity of the gluteus maximus and biceps femoris muscles as compared to the extension with rotation and lateral bending exercises. The extension with trunk rotation exercise showed significantly greater activation in the thoracic and lumbar levels of the erector spinae and in the latissimus dorsi as compared to the other exercises. The index measuring subjective difficulty was significantly lower in the simple trunk extension exercise as compared to the extension with trunk rotation and extension with lateral bending exercises.

Conclusion: The present study suggests that extension with trunk rotation has the advantage of stimulating the para-spinal muscles, while simple trunk extension may not be adequate to selectively simulate the para-spinal muscles but may be appropriate for examining global trunk extensors.

Key Words: Electromyography, Sorensen test, Trunk rotation

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Ⅰ. INTRODUCTION

Reduced endurance and excessive fatigability of the trunk extensors are often related with low back pain. Identifying capacity of the trunk extensors is not only assessing the present status of the para-spinal structure but also predicting development of the future low back pain (Lee et al., 1999; Juan-Recio et al., 2017). Among the test for evaluating back endurance, the Sorensen test is one of the general methods for identifying the endurance capacity of the trunk extensors (Kurz et al., 2016; Lee et al., 1999). The test is proceed as isometric form, which the subject is prone position, the lower body below the superior border of the anterior iliac crest is fixed to bench with strap, and the upper body is exposed to the gravity without any support. The time for maintaining this position is the criteria to assess the para-spinal muscle endurance. Despite wide use of this test, its validity to specifically measure lumbar para-spinal muscle fatigue is not well known.

Following the clinical literature, trunk extensors are composed of lumbar and thoracic erector spinae muscles as well as hip extensors, which are considered as posterior spine muscle chain (De Ridder et al., 2013). Through the Sorensen test, endurance of the overall trunk extensors could be evaluated, but not for the selective evaluation of the thoracic and lumbar extensors. Several previous researches have investigated variations of endurance test for activating the thoracic and lumbar musculature (Da Silva et al., 2005; Elfving & Dedering, 2007). It was reported that back extension with sitting position could be a useful method of localizing the effects of endurance training on the muscles of the lumbar and thoracic region (Elfving & Dedering, 2007). However, Da Silva et al. (2005) compared three different endurance tests and represented that paraspinal muscle fatigue was higher with general Sorensen and upright tests than with the lifting procedure. Although, previous studies suggests alternatives of endurance test in assumption that general Sorensen test is inadequate for evaluating para-spinal muscle endurance, there still was a necessity of developing back extension endurance test.

As the one of the stress occurring back extension endurance test, the Sorensen test has performed in the single primary plane of spine (flexion and extension). This single plane movement remains possibility of adopting alternative neuromuscular strategies of enhancing contribution of hip extensors, despite in case of decreased para-spinal muscle endurance (Kankaanpää et al., 1998). Theoretically, the function of the para-spinal muscle is not only the trunk extension but also trunk lateral bending and trunk rotation (Muscolino, 2012). However, there is no study which investigated the back endurance test adding rotational and lateral bending component. Therefore, present study was to investigate the way of effectively stimulating the erector spinae muscles by adding component of trunk rotation and lateral bending to general back extension.

Ⅱ. MATERIALS AND METHOD

1. PARTICIPANTS

18 asymptomatic males were recruited from a local university using convenience sampling. The subjects had a mean±SD age of 21.94±2.24 (range 20–28) years and performed weight training twice per week. Subjects had no history of back pain or discomfort in the past 6 months. For preventing potential influence of fatty tissue on measuring surface electromyography activity, participants with a body mass index (BMI) of 25 or higher were excluded. The height and weight of the final sample populations were 175.07±5.26 cm and 66.60±8.39 kg, respectively. The average BMI was 21.69±2.23 kg/m^2.

Fig. 1. Three conditions of endurance tests. A: Test with trunk extension (TE), B: Test with trunk extension and lateral bending (TB), C: Test with trunk extension and rotation (TR).

All participants gave informed written consent according to the protocol approved by Kaya University Faculty of Health Science Human Ethics Committee (Kaya IRB-2017194).

2. INSTRUMENTATION

Surface electromyography (sEMG) data were collected using a wireless EMG system (Free EMG300, BTS Bioengineering, Italy). The sEMG signals were sampled with a 1000 Hz frequency. The data obtained were computerized with the EMG acquisition software (BTS). The skin was prepared for EMG measurement by cleaning the electrode site with alcohol. Five surface electrodes were placed on the following muscles of the right dominant side: latissimus dorsi (LD) lateral to T9 over the muscle belly; erector spinae of T12 (ES-T12) approximately 2 cm lateral from the spine; erector spinae of L3 (ES-L3) at the level of the iliac crest, approximately 2 cm form the spine over the muscle mass rib; gluteus maximus (GM) at half the distance between the trochanter (hip) and the sacral vertebrae in the middle of the muscle on an oblique angle; biceps femoris (BF) at the muscle in the center of the back of the thigh, approximately half the distance from the gluteal fold to the back of the leg (Cram et al., 1998).

3. PROCEDURES

After 5 minutes of practice and rest time for acclimation to the test variations, each subject has performed three different endurance tests (Fig. 1). For preventing muscular fatigue 30 minutes of rest time between tests are given to participant. Commonly, subject's lower body below the superior border of the anterior iliac crest is fixed to bench with strap, and the upper body is exposed to the gravity with sling support.

For the general Sorensen test including trunk extension (TE), subjects extend their trunk to horizontal level and maintain the posture without sling support. For the test with trunk extension and lateral bending (TB), subjects laterally flexed their trunk to horizontal level and maintain the posture without sling support. For the test with trunk extension and rotation (TR), subjects extend their trunk and rotate to right, and maintain the posture without sling support. During three conditions of tests, subjects are instructed to maintain the posture as possible. Subjects conducted a trial under each test condition, and sEMG data were collected over a period of test duration.

Before collecting sEMG data during tests variations, each subject performed two trials at maximal voluntary muscle contraction (MVIC) for the included muscles against manual resistance. The highest value between the two MVIC trials was used for the normalization procedure. After performing each test, subject reply the subjective difficulties using borg scale. The normalized values of LD, ES-T10, ES-L3, GM, BF are presented as %MVIC. The three values including normalized EMG values, borg

Table 1. Descriptive statistics of normalized EMG data (%MVIC) of the five muscles, subjective difficulty index (Borg scale), and endurance time during three conditions of back endurance tests.

Variables	General trunk extension	Extension with trunk lateral bending	Extension with trunk rotation	p-value
LD	20.35±11.56[a]	26.35±18.43[a]	42.55±21.90[b]	0.00
ES-T10	64.23±15.97[a]	52.67±12.99[b]	86.33±16.75[c]	0.00
ES-L3	76.06±16.55[a]	51.04±13.74[b]	87.14±12.68[c]	0.00
GM	55.84±40.61[a]	31.28±20.83[b]	35.03±19.15[b]	0.00
BF	45.69±36.11[a]	18.87±11.82[b]	41.62±26.35[a]	0.00
Borg Scale	10.83±1.15[a]	15.16±1.29[b]	13.11±1.52[c]	0.00
Endurance time (s)	176±46.13[a]	55.00±24.93[b]	57.61±24.97[b]	0.00

Unit: %MVIC, LD: latissimus dorsi, ES-T10: erector spine – T10 level, ES-L4: erector spine –L3 level, GM: gluteus maximus, BF: biceps femoris, [a,b,c] values with a column with different superscripts letters are significantly different each groups (*p*<0.05)

scale values, and duration time were used for statistical analysis.

4. STATISTICAL ANALYSIS

The root mean square of sEMG data during the test was obtained with a widow length of 0.125s and averaged. The data are expressed as the %MVIC relative to normalized data. PASW Statistics (version 18.0 SPSS, Chicago, IL, USA) was used to determine the significance of differences in %MVIC values between test conditions. The Friedman analysis was used to determine the effects of endurance test variation on the EMG data. When significant difference was observed, the Wilcoxon's singned rank test has performed for pair-wise comparison between each conditions. In all analyses, $p<0.05$ was taken to indicate statistical significance.

Ⅲ. RESULTS

The LD activity showed significant differences in factor of test conditions, which was higher with the TR compared with the TE and TB ($p<0.05$). Similarly, the normalized sEMG data for the ES-T12, and for the ES-L3 differed significantly between test conditions, which was also higher with the TR compared with the TE and TB ($p<0.05$) (Table 1).

The TE condition caused significant increases in GM activity compared with the other test variations ($p<0.05$). The normalized sEMG data for the BF differed significantly between test conditions, which the both of TE and TR conditions showed significantly higher sEMG values of the BF than the TB ($p<0.05$).

Subjective difficulties representing borg scale was significantly higher in TB condition than the TE and TR conditions ($p<0.05$). The endurance time for performing TE was significantly greater than other conditions ($p<0.05$).

Ⅳ. DISCUSSION

Present study investigated the muscular activities of the para-spinal and hip extensors during three varieties of trunk endurance tests. Clinical literature and previous study suggest endurance time for resisting one's body weight is different between peoples with and without low back pain (Kankaanpää et al., 1998; del Pozo-Cruz et al., 2014). Moreover, relatively reduced endurance time could be a predictor for inducing low back pain (Lee et al., 1999; del Pozo-Cruz et al., 2014). While the low back pain is frequently occurred within lumbar region, endurance test such as the Sorensen test examines the overall back extensors which include hip extensors as well as lumbar extensors. Similar to previous studies which suggest modification of the endurance tests (Champagne et al., 2008; Juan-Recio et al., 2017), present study is to suggest a way to selectively examine the endurance capacity relating lumbar extensor.

An important finding in this study was that adding lateral bending and rotation component showed different muscular activity of trunk extensors, compared with general extension test. Adding trunk rotation to general extension test was greatly activated the latissimus dorsi, 12th level of thoracic extensors, and 3rd level of lumbar extensors. Anatomically, erector spinae and tranversospinalis groups not only extend spine but also rotate and laterally flex the spine (Muscolino, 2012). Because the function of the rotation depends on the relatively deep tranversospinalis muscles such as multifidus and rotatores, adding rotation component could be an option for evaluating relatively deep spinal muscles. Considering muscular function, elevated activations of para-spinal muscles were natural results. Pizouzi et al. (2006) reported that patients with low back pain demonstrate increased trunk extensor muscle activity during submaximal rotational efforts. Although present study investigated muscular activity in asymptomatic population, elevated extensor activity during rotational efforts are similar to previous results.

Previous biomechanical studies alarmed the risk of generating back pain in trunk rotation and lateral bending combined with trunk flexion and extension (Hoogendoorn et al., 2000; McGill, 1992). It was demonstrated that the spinal movement strayed from neutral zone could induce the pain symptom (Panjabi, 2003). Without supporting active structure such as muscular activation, repetitive and drastic combined movements with trunk rotation or lateral bending might contributes to generating low back pain. However, the endurance test is to evaluate the capacity of active structure so that the test should selectively evaluate targeted active structure with preventing drastic movements. When a subject could not maintain the test position, for preventing injury of passive structure, present study used suspension device for excluding drastic movements.

Previous study demonstrated that increased recruitment of extensor muscle could not be interpreted as generating early muscle fatigue (Bottle & Strutton, 2012). Because the present study could not measure the median frequency due to difference in maintaining test time between each subject, it is not certain whether each test induce the muscle fatigue or not.

However, the test time for maintaining position was significantly different between conditions, which were significantly greater in the general extension test than other conditions. Reduced endurance time were represented in both modified extension tests. Considering muscular activities that trunk extension with rotation significantly elevates the trunk extensor muscle activities, reduced time for the trunk extension with rotation condition might be associated with over-activity of the trunk extensors such as erector spinal and latissimus dorsi muscles. According to recent finding, mean duration for the extension test was from 100s to 157s in subject to asymptomatic population (Demoulin et al., 2016; del Pozo-Cruz et al., 2014). Even for the subject with low back pain, the duration was over 60s (del Pozo-Cruz et al., 2014). For reducing test time as well as selectively evaluating trunk extensors, adding rotation component might be an option.

This study had several limitations. The first was the lack of EMG information for the other trunk muscles, such as the external oblique and gluteus maximus, which may still be influenced by test conditions. Second, our results cannot be generalized because of the limited number of subjects included in the study. Finally, excessive lordosis caused by the anterior tilt of the pelvis cannot be measured with limited video analysis. Further investigations are needed taking these limitations into consideration.

Ⅴ. CONCLUSION

Present study suggests extension adding trunk rotation test had advantages of stimulating the para-spinal muscles, while the simple trunk extension test could not be adequate for selectively simulate the para-spinal muscles.

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