Original Article

Effect of the stabilization training programme in the improvement of trunk and hip muscles activations among healthy females subject: An implication for the rehabilitation experts

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Abstract:

Evidence has demonstrated that the prevalence of lower back pain (LBP) among women population is significantly higher due to the hormonal and reproductive factors such as irregular or prolonged menstrual cycle and hysterectomy. The trunk and hip muscles are considered the most affected muscles in LBP patients and as such proper training of these muscles could give a substantial benefit to the patients. Different types of exercises programmes exist, however, the appropriate training that could be applicable in stimulating certain groups of muscles for a specified gender remains a challenge. As a starting point, this study aims to identify the effectiveness of a stabilisation training programme (SBTP) in developing and stimulating the trunk and hips muscles of female's subjects. 25 healthy female with normal BMI and ages range from 19 to 24 years underwent five sets of stabilisation exercises three times a week for five weeks. Electromyography (EMG) data were collected from 5 muscles of rectus abdominus, external oblique, multifidus, gluteus maximus and gluteus medius. The readings from the EMG were compared after the five weeks interventions (pre and post). An independent t-test was applied to the data gathered to examine the efficacy of the SBTP between pre and post on the targeted muscles. A statistically significant difference of muscle activations between the pre and post on all the assessed muscles were obtained $p < 0.05$. This result implies that SBTP intervention is efficient in stimulating the females' pelvic muscles activations. SBTP could be a practical measure for prevention and rehabilitation of LBP.

Key Words: - Stabilisation training, Muscle activations, Pelvic muscles, Lower back pain

Introduction

Training programmes devised to enhance spinal stabilisation have earned acceptance in the general rehabilitation of patients with LBP; however, the evidence for the efficacy of this technique is inadequate and ambiguous ((BenDebba, Torgerson, & Long, 2000). The few investigations that have considered specific stabilisation exercise programs among patients with LBP in more homogenous populations have demonstrated some promising effects (O'sullivan, Phyt, Twomey, & Allison, 1997). The authors randomised patients with recurrent LBP and a radiologic diagnosis of spondylolysis or spondylolisthesis to obtain either stabilisation exercises or usual care given by a general practitioner. There were statistically significant reductions in pain and disability at a 30-month follow-up. Moreover, Byström, Rasmussen-Barr, and Grooten, (2013) inferred that stabilisation training at moderate intensity could be beneficial in the long run for alleviating disability and pain over basic exercises. Additionally, some studies have suggested that exercise modalities can be designed to prompt the supporting muscles of the spine in a pattern that tends out to be valuable for some patients with LBP (Hides, Richardson, & Jull, 1996; O'sullivan et al., 1997). Likewise, Delitto, Erhard, and Bowling, (1995); Ogon et al., (1997) pointed out that the study of irregular movement patterns during active trunk motion is crucial in the examination of lumbar segmental instability. Based on this background, it could, therefore, be deduced that designation of an appropriate training programme could be beneficial when the right and relevant muscles are targeted. The activations of muscles that are involved in the mobility process could be useful in reduction or rehabilitation of LBP patients and also could serve as a training regimen for a healthy individual to prevent future occurrences of LBP.

The Selected Muscles Examined in the study

The rectus abdominis (RA) is located at the pubic crest and pubic symphysis and inserted at the cartilage of the 5th to seventh ribs as well as the xiphoid process. When contracted, the RA flexes the vertebral line and compresses the stomach (Moret & Fellay, 2013). The RA is believed to possess a high recruitment threshold, which can be substantial in bracing the spine for high-load actions such as when pushing and lifting

heavy objects (Comerford & Mottram, 2006). It has been reported that the RA is mainly activated during general and abdominal exercises that assist in increased gross spinal movements (Oladipo, Aigbogun, & Akani, 2015). The External or exterior obliques muscle in the other hand is situated on the inferior eight steaks and attach to the iliac crest. Previous investigators have revealed that the lateral fibres of the exterior oblique compress the belly and flex the vertebral column (Moret & Fellay, 2013). It was described further that once there is a unilateral contraction of the external oblique, the vertebral column is laterally flexed and rotated. In another perspective, the multifidus is the central muscle for lumbar segmental stability, and it is originated inside the posterior sacrum, and fine iliac and it is inserted in the spinous of the backbone except cervical 1 and this muscle acts as trunk area lateral flexion and aids in trunk extension (Patton, 2015). The Gluteal Muscles comprise of 3 muscles that make up the bottom namely; Gluteus Maximus, Gluteus Medius and the Gluteus Minimus (Liebenson, 2007). Evidence has shown that Gluteus medius is involved in the stability of the pelvis (Kendall, Schmidt, & Ferber, 2010). Similarly, Wilson, Ferris, Heckler, Maitland, and Taylor, (2005) revealed that Gluteus medius, in particular, acts an important role in maintaining posture, the trunk upright when the feet of the opposite side are in reality raised from the ground in walking and running, where the body weight tends to act by yanking the pelvis downwards inside the unsupported side. This tendency is counteracted by gluteus medius and gluteus minimus on the supporting side that acts from below and applies a great traction around the stylish bone to result in a small rising of the pelvis around the unsupported side. In a nutshell, all the aforementioned muscles are considered in the present study due to their significant roles in transferring forces from the lower extremity up to the backbone during regular physical and daily activities as evident from the existing literature (Beckman & Buchanan, 1995; Devita, Hunter, & Skelly, 1992).

Purpose and Potential Impact of the Study

Research has demonstrated that the prevalence of LBP among women population is significantly higher due to the Hormonal and reproductive factors such as irregular or prolonged menstrual cycle and hysterectomy as compared to males (Wijnhoven, de Vet, Smit, & Picavet, 2006). In the other hand, it has been reported that to identify the effectiveness of a particular intervention programme, the first way to begin could be with healthy subjects after that the potential findings could be safely applied to the patient's (Abdullah et al., 2016; Youdas et al., 2008). To this effect, the study examined the effectiveness of SBTP in improving the said targeted muscles activations of healthy female subjects. The study aims at drawing the attention of the physiotherapist, trainers and other stakeholders to determine the most appropriate training programme capable of given maximum effects in developing and stimulating the lumber muscles of female's subjects which will consequently serve as a guide for application to the reduction and rehabilitations of LBP amongst female patients.

Materials and Methods

Participants

A total of 25 healthy female subjects with normal BMI of 18.5 to 24.9 kg/m² and without any record for current or previous lower extremity or back problems with ages range of 19 to 24 years were recruited to participate in the study. The participants who volunteered to take part in this study were from the Faculty of Health Sciences of the Universiti Sultan Zainal Abidin. Written consent was obtained, and all the participants signed consent forms. All the exercises procedures, protocol, and equipment for this study were authorised by the Research Ethics Board of the Universiti Sultan Zainal Abidin with an approval number of UniSZAC/628-1jld2 (02).

Selected Exercises for the study

The following stability based exercise were selected and applied in the study. The selections of the exercises were carefully made based on their ability in stabilising the muscles under investigation.

Table 1: Selected exercises and the targeted muscles

Name of exercise	Muscle	How to perform	Reference
(a) curl up	Rectus abdominal	You need to lie on your back on an exercise mat or bed. Bend both knees until your feet are flat on the floor. With your feet away from the floor, lift your head and shoulders until your shoulder blades are off the floor. Hold for a moment at the top of the movement, and then slowly lower your back. Hold on 5s.	(Sarti, Monfort, Fuster, & Villaplana, 1996; Youdas et al., 2008)
(b) plank side	External oblique	Lie on your side and brace your core muscles. Raise yourself up on the side of one foot and with your elbows raise your trunk off the floor and hold on 5s.	(Ekstrom, Osborn, & Hauer, 2008; Okubo et al., 2010)
(c) back bridge	Multifidus	Lie on your back with your knees bent, placing your heels close to your	(Koumantakis, Watson, & Oldham, 2005; Stevens et al., 2007)

buttocks. Keep your arms at your sides with palms down, squeeze your gluteus and raise your hips off the floor to get into the bridge position and hold on 5s.

(d) plank hip extension	Gluteus maximus	Start by lying prone on your elbows in planks with trunk, hips, and knees in neutral alignment (left). Lift your dominant leg off the ground, flex the knee of your dominant leg, and extend the hip past the neutral hip alignment by bringing the heel in.	(Distefano, Blackburn, Marshall, & Padua, 2009; Selkowitz, Beneck, & Powers, 2013)
(e) plank hip abduction	Gluteus medius	Dominant leg down. Begin with a side plank position. You are reminded to keep shoulders, hips, knees, and ankles in line bilaterally, and then to rise to plank position with your hips lifted off the ground to achieve a neutral alignment with your trunk, hips, and knees. While balancing on your elbows and feet, raise the top leg into abduction (right) for one beat and then lower your leg for one beat.	(Serner et al., 2013)

Figure 1. Selected Stabilisation exercises used in the study (a) Curl up; (b) Plank side bridge; (c) Back bridge; (d) Plank hip extension; (e) Plank Hip Abduction.

Experimental Protocol

The participants were given a set of stabilisation training as shown in Fig 1 for a period of five weeks. Before the beginning of the exercises, the initial measurement of the muscles activations was taken at a zero week (pre). Electromyography (EMG) data were collected from 5 muscles during the exercises performance (Rectus abdominal, External oblique, Multifidus, Gluteus maximus and medius), and the readings from the EMG were compared after the five weeks interventions (pre and post).

Data Collection Procedure

Prior to electrode placement, each subject was familiarised with the procedures by being instructed, and by practising the muscle tests and exercises performed. The researchers taught all the participants on how to perform each exercise using explanations and pictures. Dual disposable silver/silver chloride surface area recording electrodes were used. EMG data were gathered from the rectus abdominis, exterior oblique, lumbar multifidus, gluteus maximus and gluteus medius. For the rectus abdominis muscle, the electrodes were placed 3 cm horizontal and 3 cm above the umbilicus. The electrodes were positioned midway between the anterior fine iliac spine and the ribs cage for the exterior oblique abdominis muscle. Intended for the lumbar multifidus muscle mass, the electrodes were put 2 cm lateral towards the lumbosacral junction. The electrodes for the gluteus medius muscle were placed above the gluteus maximus muscle and closer to the iliac crest around the lateral side of the pelvis. For the gluteus maximus muscle, electrodes were placed in the centre from the muscle belly between the extensive edge of the sacrum as well as the posterosuperior edge of the higher trochanter. The reference electrode was located over the anterior superior iliac spine. All the procedures for the electrodes placement were conducted by the recommendations of the previous researchers (Gracovetsky, 2010; Taha et al., 2017). A detail description of the entire data collection procedure is provided in Figure 2.

Figure 2: A flow chart during the data collection process

Figure 2 projects the flow chart organisation during the data collection process. The time for the warm up, preparation of the sites attachment of the electrodes, the time taken for each exercise as well as the rest period interval are displayed. The procedures for all the steps were performed in accordance with the recommendations by the previous researchers (Ekstrom et al., 2008; Ingersoll & Knight, 1991).

Statistical Analysis

The independent t-test analysis was employed in this study to determine whether there is a significant difference between the pre and post of the training modalities as well as to compare the efficacy of the interventions training in the improvement of the muscle activations between the pre and the post measurement. The periods (pre and post) were used as the independent variables while the average electrical activities of all the selected muscles were treated as the dependent variables. All the statistical analysis was conducted using XLSTAT add in software version 2014 for Windows at a confidence level of $p \leq 0.05$.

Result

Table 2 reveals the descriptive statistics of the pre and post stabilisation training programme (SBTP) on the muscles evaluated. The period of the intervention (pre and post) the number of the participants, the minimum, maximum scores, mean as well as the standard deviation of each variable is displayed. It can be

noticed from the table that the average of the post-intervention measurement is larger than the pre-measurement demonstrating that the average muscle activations of the post are considerably higher as compared to the pre.

Table 2: Descriptive Statistics of the stabilisation training intervention programme on the muscles assessed.

Muscle types	Intervention period	N	Min.	Max.	M	SD
Rectus abdominus	Pre	25.00	27.84	438.96	132.13	134.42
	Post	25.00	78.76	1933.23	372.87	439.46
External oblique	Pre	25.00	46.16	497.65	117.15	104.89
	Post	25.00	91.96	1378.43	322.24	358.39
Multifidus	Pre	25.00	30.88	377.86	110.84	97.73
	Post	25.00	56.72	1409.28	325.28	334.10
Gluteus maximus	Pre	25.00	21.12	501.94	136.29	146.31
	Post	25.00	76.02	1259.33	342.20	292.61
Gluteus medius	Pre	25.00	15.07	494.68	142.46	144.57
	Post	25.00	88.21	1031.67	313.50	197.58

Table 3 shows the inferential statistics of the pairwise comparison carried out as a follow-up for the *t*-test. From the table, *t* observed, *t* critical, the degree of freedom the difference between the pre and post evaluations and the significant levels are indicated. It can be observed that there is a statistically significant difference between the pre and post on the muscle activations in all the assessed muscles of Rectus abdominus, External oblique, Multifidus, Gluteus maximus and Gluteus medius $p < 0.05$. This result implies that SBTP is intervention is efficient in increasing the said muscles activations of the participants observed in the study.

Table 3: Inferential Statistics of the stabilisation training intervention programme on the muscles evaluated.

Muscle types	t(obs.)	t(crtcl)	DF	D	Sig
Rectus abdominus	-2.62	2.01	48	-240.7	0.011
External oblique	-2.75	2.01	48	-205.1	0.008
Multifidus	-3.08	2.01	48	-214.4	0.003
Gluteus maximus	-3.15	2.01	48	-205.9	0.002
Gluteus medius	-3.49	2.01	48	-171	0.001

Discussion

The overall finding of the SBTP intervention and the electromyography activities of the muscle experimented in the present study have demonstrated that the SBTP is efficient in the enhancement of the activations of the assessed participant's muscles. The evidence given in Table 2 and 3 have shown that trunk and hip muscles of the females' participants in the study have reacted to the training programme implemented. The results indicated that SBTP could be effective as rehabilitation exercises in females' subjects. The efficacy of SBTP in the improvement of muscles electrical activities has been reported in various literature.

The purposes of stabilisation exercise are to develop muscular motor sequences to enhance spinal balance, prevent irregular micro-motion, and decrease related pain (Olufemi & Musa, 2016; Gasibat & Simbak, 2017). Different investigations that examined muscle onset and electromyographic sequences have proposed that some specific muscles are essential stabilisers measure of stability (Richardson, Jull, Hodges, & Hides, 1999). Moreover, the findings of the present study is in agreement with the results obtained by Cholewicki and McGill, (1996); Gardner-Morse, Stokes, and Laible, (1995) who assessed stability training in their researches using various muscles and have consistently recognize that all the selected muscles perform a role in providing spine stability and that the motor sequences of co-contraction between the entire supplement of muscles are of absolute significance to secure stability and reduce pain. Despite the fact that, the exercises considered in this research are generally reported in the literature as targeting a distinct muscle group (Hides, Jull, & Richardson, 2001), electromyography studies apply in this study demonstrate that the exercises could stimulate combinations of muscles in a manner that reinforces overall spinal stability.

Furthermore, the present study is in line with some previous investigations which indicated that training programs can be devised to stimulate the stabilising muscles of the spine in a form that turns out to be efficient for some subgroups of patients with LBP (Hides et al., 1996; O'sullivan et al., 1997). Similarly, Delitto et al., (1995); Ogon et al., (1997) have indicated that the perception of abnormal movement patterns during active trunk motion is important in the analysis of lumbar segmental instability (LSI). The existence of abnormal movements may serve as an incapacity to satisfactorily regulate lumbar movement and point to a requirement for stabilisation training. Patients with LSI have been referred to as a special subgroup of patients with LBP (Delitto et al., 1995; Panjabi et al., 1994). LSI has been interpreted as a situation in which there is a decline of rigidity

between spinal movement portions, such that the commonly permitted external loads result in discomfort, impairment or otherwise renders neurologic structures at risk. In such cases, stabilisation exercise could help to strength the muscles and offer some comforts to the patients.

Conclusion

The results of the present study have demonstrated that the stabilisation training programme observed in the study have been effective in improving the muscles activations of the subjects within the five weeks training interventions period. The stabilisation intervention has appeared to be effective in stimulating the rectus abdominal, external oblique, multifidus, gluteus maximus and gluteus medius muscles. Moreover, the study has shown that the utilisation of surface electromyography signals in detecting muscles activations is non-trivial as it permits the researchers to accurately identify the best intervention training programme that can enhance the activations of the lumbar muscles amongst healthy female's subjects which would, in the long run, be applicable to the female's patients with record of LBP.

Conflicts of interest - The authors have no conflicts of interest to declare.

References

- Abdullah, M. R., Eswaramoorthi, V., Musa, R. M., Maliki, M., Husin, A. B., Kosni, N. A., & Haque, M. (2016). The Effectiveness of Aerobic Exercises at difference Intensities of Managing Blood Pressure in Essential Hypertensive Information Technology Officers. *Journal of Young Pharmacists*, 8(4).
- Beckman, S. M., & Buchanan, T. S. (1995). Ankle inversion injury and hypermobility: effect on hip and ankle muscle electromyography onset latency. *Archives of Physical Medicine and Rehabilitation*, 76(12), 1138–1143.
- BenDebba, M., Torgerson, W. S., & Long, D. M. (2000). A validated, practical classification procedure for many persistent low back pain patients. *Pain*, 87(1), 89–97.
- Byström, M. G., Rasmussen-Barr, E., & Grooten, W. J. A. (2013). Motor control exercises reduces pain and disability in chronic and recurrent low back pain: a meta-analysis. *Spine*, 38(6), E350–E358.
- Cholewicki, J., & McGill, S. M. (1996). Mechanical stability of the in vivo lumbar spine: implications for injury and chronic low back pain. *Clinical Biomechanics*, 11(1), 1–15.
- Comerford, S., & Mottram, S. (2006). Transverse training: a waste of time in the gym. *FitPro Network (Apr-May)*[online]. Available from URL: [Http://www. Kineticcontrol. Com/publication. Asp](http://www.kineticcontrol.com/publication.asp) [Accessed 2008 Oct 29].
- Delitto, A., Erhard, R. E., & Bowling, R. W. (1995). A treatment-based classification approach to low back syndrome: identifying and staging patients for conservative treatment. *Physical Therapy*, 75(6), 470–485.
- Devita, P., Hunter, P. B., & Skelly, W. A. (1992). Effects of a functional knee brace on the biomechanics of running. *Medicine and Science in Sports and Exercise*, 24(7), 797–806.
- Distefano, L. J., Blackburn, J. T., Marshall, S. W., & Padua, D. A. (2009). Gluteal muscle activation during common therapeutic exercises. *Journal of Orthopaedic & Sports Physical Therapy*, 39(7), 532–540.
- Ekstrom, R. A., Osborn, R. W., & Hauer, P. L. (2008). Surface electromyographic analysis of the low back muscles during rehabilitation exercises. *Journal of Orthopaedic & Sports Physical Therapy*, 38(12), 736–745.
- Gardner□Morse, M., Stokes, I. A. F., & Laible, J. P. (1995). Role of muscles in lumbar spine stability in maximum extension efforts. *Journal of Orthopaedic Research*, 13(5), 802–808.
- Gasibat, Q., & Simbak, N. Bin. (2017). Moderation of Back pain by Rehabilitation Exercises□; Multifidus Muscle ' Perspective, *IOSR Journal of Sports and Physical Education*, 4(1), 14-18.
- Gracovetsky, S. (2010). Non Invasive Assessment of Spinal Function. *Automatizing the Physical Examination. Canada: Aardvark Global Publishing*.
- Hides, J. A., Jull, G. A., & Richardson, C. A. (2001). Long-term effects of specific stabilizing exercises for first-episode low back pain. *Spine*, 26(11), e243–e248.
- Hides, J. A., Richardson, C. A., & Jull, G. A. (1996). Multifidus Muscle Recovery Is Not Automatic After Resolution of Acute, First□Episode Low Back Pain. *Spine*, 21(23), 2763–2769.
- Ingersoll, C. D., & Knight, K. L. (1991). Patellar location changes following EMG biofeedback or progressive resistive exercises. *Medicine and Science in Sports and Exercise*, 23(10), 1122–1127.
- Kendall, K. D., Schmidt, C., & Ferber, R. (2010). The relationship between hip-abductor strength and the magnitude of pelvic drop in patients with low back pain. *Journal of Sport Rehabilitation*, 19(4), 422–435.
- Koumantakis, G. A., Watson, P. J., & Oldham, J. A. (2005). Trunk muscle stabilization training plus general exercise versus general exercise only: randomized controlled trial of patients with recurrent low back pain. *Physical Therapy*, 85(3), 209.
- Liebenson, C. (2007). *Rehabilitation of the spine: a practitioner's manual*. Lippincott Williams & Wilkins.
- Moret, M., & Fellay, J. (2013). “ Core stability training” et puissance musculaire: une méta-analyse. HES-SO Valais Wallis-Haute Ecole de Santé.

- O'sullivan, P. B., Phytty, G. D. M., Twomey, L. T., & Allison, G. T. (1997). Evaluation of specific stabilizing exercise in the treatment of chronic low back pain with radiologic diagnosis of spondylolysis or spondylolisthesis. *Spine*, 22(24), 2959–2967.
- Ogon, M., Bender, B. R., Hooper, D. M., Spratt, K. F., Goel, V. K., Wilder, D. G., & Pope, M. H. (1997). A Dynamic Approach to Spinal Instability: Part II: Hesitation and Giving Way During Interspinal Motion. *Spine*, 22(24), 2859–2866.
- Okubo, Y., Kaneoka, K., Imai, A., Shiina, I., Tatsumura, M., Izumi, S., & Miyakawa, S. (2010). Electromyographic analysis of transversus abdominis and lumbar multifidus using wire electrodes during lumbar stabilization exercises. *Journal of Orthopaedic & Sports Physical Therapy*, 40(11), 743–750.
- Oladipo, G. S., Aigbogun, E. O., & Akani, G. L. (2015). Angle at the medial border: the spinovertebra angle and its significance. *Anatomy Research International*, 2015.
- Olufemi, A. J., & Musa, R. M. (2016). Assessment of wellness status among a multi-ethnic based adult sample. *Int J Phy Edu Sports Health*, 3(4), 299–301.
- Panjabi, M. M., Lydon, C., Vasavada, A., Grab, D., Crisco III, J. J., & Dvorak, J. (1994). On the understanding of clinical instability. *Spine*, 19(23), 2642–2650.
- Patton, K. T. (2015). *Anatomy and physiology*. Elsevier Health Sciences.
- Richardson, C. A., Jull, G. A., Hodges, P. W., & Hides, J. A. (1999). *Therapeutic exercise for spinal segmental stabilization in low back pain: scientific basis and clinical approach*. Churchill Livingstone.
- Sarti, M. A., Monfort, M., Fuster, M. A., & Villaplana, L. A. (1996). Muscle activity in upper and lower rectus abdominus during abdominal exercises. *Archives of Physical Medicine and Rehabilitation*, 77(12), 1293–1297.
- Selkowitz, D. M., Beneck, G. J., & Powers, C. M. (2013). Which exercises target the gluteal muscles while minimizing activation of the tensor fascia lata? Electromyographic assessment using fine-wire electrodes. *Journal of Orthopaedic & Sports Physical Therapy*, 43(2), 54–64.
- Serner, A., Jakobsen, M. D., Andersen, L. L., Hölmich, P., Sundstrup, E., & Thorborg, K. (2013). EMG evaluation of hip adduction exercises for soccer players: implications for exercise selection in prevention and treatment of groin injuries. *British Journal of Sports Medicine*, bjsports-2012.
- Stevens, V. K., Vleeming, A., Bouche, K. G., Mahieu, N. N., Vanderstraeten, G. G., & Danneels, L. A. (2007). Electromyographic activity of trunk and hip muscles during stabilization exercises in four-point kneeling in healthy volunteers. *European Spine Journal*, 16(5), 711–718.
- Taha, Z., Musa, R. M., Abdullah, M. R., Razman, M. A. M., Lee, C. M., Adnan, F. A., ... Haque, M. (2017). The Application of Inertial Measurement Units and Wearable Sensors to Measure Selected Physiological Indicators in Archery. *Asian Journal of Pharmaceutical Research and Health Care*, 9(2), 85–92.
- Wijnhoven, H. A. H., de Vet, H. C. W., Smit, H. A., & Picavet, H. S. J. (2006). Hormonal and reproductive factors are associated with chronic low back pain and chronic upper extremity pain in women—the MORGEN study. *Spine*, 31(13), 1496–1502.
- Wilson, J., Ferris, E., Heckler, A., Maitland, L., & Taylor, C. (2005). A structured review of the role of gluteus maximus in rehabilitation. *NZ J Physiother*, 33(3), 95–100.
- Youdas, J. W., Guck, B. R., Hebrink, R. C., Rugotzke, J. D., Madson, T. J., & Hollman, J. H. (2008). An electromyographic analysis of the Ab-Slide exercise, abdominal crunch, supine double leg thrust, and side bridge in healthy young adults: implications for rehabilitation professionals. *The Journal of Strength & Conditioning Research*, 22(6), 1939–1946.