Journal of Engineering and Applied Sciences 13 (Special Issue 14): 10875-10881, 2018
ISSN: 1816-949X

The Comparisons of Different Abdominal Drawing-in Maneuver During Plank Exercises on Trunk Stability

Eun-Song Kim, Da-Song Gil, Su-Bin Kim, Dong-Yeop Lee,
Ji-Heon Hong, Jae-Ho Yu and Jin-Seop Kim
Department of Physical Therapy, Sun Moon University, Asan, Republic of Korea

Abstract: To measure the thickness of Transversus Abdominis (TrA), Internal Oblique (IO), External Oblique (EO) and Multifidus (MF) and compare the effects on trunk stability according to the performing abdominal drawing-in manuever during plank exercises. Thirty healthy male and female adults were recruited. Subjects perform the plank exercises after measuring thickness of TrA, IO, EO and MF in resting position. When performing the General Plank(GP), General Plank with Abdominal drawing-in maneuver (GPA), Unstable Surface of Plank (USP) and Unstable Surface of the Plank with Abdominal drawing-in maneuver (USPA), we measured three times and used the value of measurements. All measurements were used in one way repeated ANOVA. The results of study, resting time and each plank exercises showed significant differences in TrA, IO, MF muscles. In the comparison between each plank exercises, the TrA, IO, MF activation increased because that muscle were thicker than other plank exercises when performing GPA and USPA. These findings suggest that a plank exercise with abdominal drawing-in maneuver is useful way in trunk stability.

Key words: Plank exercise, core stability, core muscles, abdominal drawing-in maneuver, ultrasonography, unstable surface

INTRODUCTION

Core is general term for waist area such as abdominal area, pelvis and muscles located on this area that is involved with balance and movement of body and maintaining the position area called core muscles. When core muscles are trained, maintaining the balance of body and muscle strength are improved through force path from center of trunk or waist area to upper and lower body (Brill *et al*., 2002). Core stability exercise not only improves the flexibility of spine but is also effective to strengthening trunk muscle and reducing the angle of spinal curvature (Akuthota *et al*., 2008). Likewise, there are many researches on core stability exercise regarding postures, tools and surface (Do and Yoo, 2015; Czaprowski *et al*., 2014; Escamilla *et al*., 2010; McGill, 2007; Akuthota and Nadler, 2004). Many of them emphasize the importance of core stability muscle (Mok *et al*., 2015).

Core stability muscle plays role on reinforcing muscle strength, improving endurance and injury prevention and rehabilitation of sports athletes (Escamilla *et al*., 2010). There is plank exercise which is an exercise to enhance core stability muscles (Hodges and Richardson, 1997a, b) and it activates the trunk stability muscles (Ekstrom *et al*., 2007). Isometric exercise, the plank exercise trains transverse abdominis (Coldron *et al*., 2008) and internal abdominal oblique which are core stability muscles (Palmer *et al*., 2015) and it is used as exercise for patient with back pain due to the reason that stability of back comes from core muscle reinforcement during plank exercise (Akuthota *et al*., 2008). Patients with back pain lack the repositioning sense due to the decline of proprioception and core muscles of them are weaker than normal that problem occurs on stability of back and pelvis which are pointed out to be causes of back pain (O'Sullivan, *et al*., 2003). Therefore, core stability is essential for proper load balance within pelvis and spine and exercise chain((Akuthota *et al*., 2008).

Muscles that are involved with trunk stability keep the balance during the movement of body and stabilize the waist (Carter *et al*., 2006; Marshall and Murphy, 2005). There are abdominal core muscles such as transverse abdominis, internal abdominal oblique (Carter *et al*., 2006) and activation of multifidus stabilize the waist of patients with back pain (Wallwork *et al*., 2009). Especially, transverse abdominis improves the stabilization of core with diaphragm, internal abdominal oblique and pelvic floor Musculature, it creates and controls the intra-abdominal pressure (Carter *et al*., 2006; Akuthota and Nadler, 2004). Also, transverse abdominis and multifidus contract faster than any other muscles in every movement of body to keep the balance of body (Willson *et al*., 2005; Hodges and Richardson, 1997a, b).

Corresponding Author: Jin-Seop Kim, Department of Physical Therapy, Sun Moon University, Asan, Republic of Korea

It was shown that plank exercise is more effective on unstable surface or narrow contact surface than on stable surface which increase the muscle activity of core muscle 5. When waist stabilization exercise was performed on unstable surfaces in every exercise other than bridge exercise, activity of trunk muscle were increased (Imai *et al*., 2010). Abdominal drawing-in method is used to stabilize waist preventing excessive anterior pelvic tilt and lordosis of waist (Oh *et al*., 2007; Kisner and Colby, 2002). It was shown that abdominal drawing-in method minimizes the angle of anterior pelvic tilt during the hip extension exercise (Radziszewski, 2007; Walker *et al*., 1987).

There are many researches about the effect of plank exercise but number of researches on comparison of plank exercise on unstable surface and plank exercise using abdominal drawing-in method is insufficient. Also, existing researches compare the muscle activation using electromyography, yet researches on measuring the thickness of muscle using ultrasonography devices.

Therefore, this research attempts to suggest the effective way for plank exercise with comparison of thickness of transverse abdominis, external abdominal oblique, internal abdominal oblique and multifidus in each exercise after performing plank on stable surface with abdominal drawing-in method, plank on unstable surface with balancing pads on each arms, plank on unstable surface with abdominal drawing-in method.

MATERIALS AND METHODS

Research participants: Test subjects to this research are 30 healthy young adults without muscular skeletal diseases such as fracture and damage of ligament and muscle and neurological diseases. Previous to the research, the content and purpose of the research are well informed to test subjects and after the agreement of research was signed by each of them, the research was conducted as shown in Table 1. This research was conducted with verification of institution review board of Sunmoon University (SM-201605-010-2).

Measurement and procedures: In this research, in order to provide unstable surface, two balance pads (Togu, GTG 400200, Germany, 2010) were used and eZono 3000 (Germany, 2011) ultrasonic device was used to measure the thickness of transverse abdominis, internal abdominal oblique, external abdominal oblique and multifidus. The frequency was set to 7~10MHz and linear probe was used in Fig. 1. Previous to experiment, during the break before exercise, thickness of transverse abdominis, internal abdominal oblique and external abdominal oblique were measured from point where it is 15 mm apart from aponeurosis vertically (Reeve and Dilley, 2009) and thickness of internal abdominal oblique was measured by connecting the transverse abdominis log line. Thickness of multifidus was measured from between L4 and L5 (Jackie, 2007). From laying down position, during third exhalation, it was measured with ultrasonic wave and during plank exercise, same procedure was performed 5 as in Fig 1-3.

Table 1: General characteristics (n = 30)

Characteristic	Values
Gender	
Male	n = 14
Female	n = 16
Age (years)	19.67±1.52
Height (cm)	168.53±8.78
Weight (kg)	60.77±11.46

Fig. 1: Ultrasonic device eZono3000, linear probe

Abdominal drawing-in method training was guided to test subjects that during the exhalation, they pull their bellybuttons upward and lumbar vertebra (Richardson and Jull, 1995). They maintained it, so that, they can breathe normally during abdominal drawing-in method (Critchley, 2002). Test subjects learned through abdominal drawing-in training with real time ultrasonic wave video which is a visual feedback (Kwon *et al*., 2011).

Test subjects were guided to bend elbow in 90° and to support surface with lower arm for plank exercise. Scapula was maintained to be stuck out, pelvis and lumbar vertebra were maintained in neutral position and from ankle to knee, hip, pelvis, spine and head were maintained position where all of these are in straight line. Arms were spread about the width of shoulders and feet were spread about the width of pelvis and ankles were supporting the surface doing dorsiflexion(Do and Yoo, 2015; Imai *et al*., 2010). First measurement was taken during break before exercise (PP) in General Plank exercise position (GP). Second measurement was taken in plank position with abdominal drawing-in method added (GPA). Third measurement was taken while two feet were on the center of balance pad to create unstable surface for lower body (USP). Fourth measurements were taken on Unstable

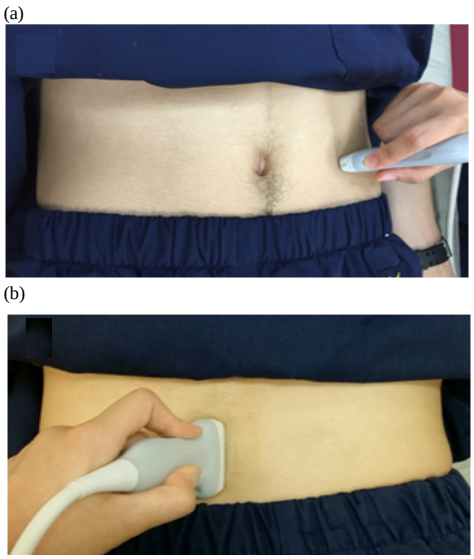

Fig. 2: a) Linear probe measure point of transverse abdominis, internal oblique and external oblique and b) Linear probe measure point of multifidus

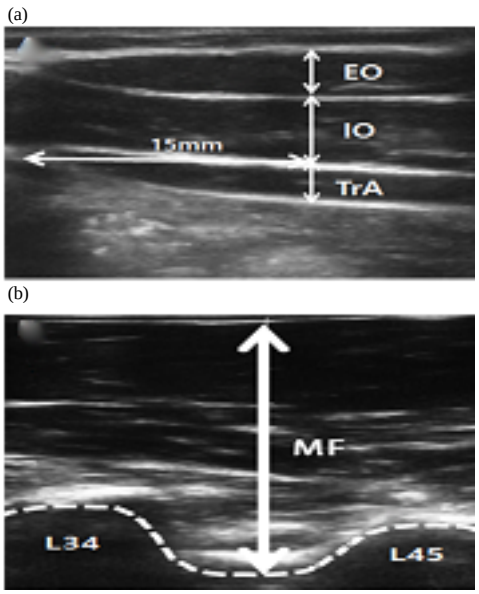

Fig. 3: a) Thickness of transverse abdominis, internal oblique and external oblique measure point and b) Thickness of multifidus measure point

Surface in Plank position with Abdominal drawing-in method added (USPA) as shown in Table 2 and Fig 4.

Experiment was conducted with test subjects having bear feet (Do and Yoo, 2015) and examiners directed subjects to keep the proper plank position. To maximize the reliability of experiment for each position,

Table 2: Methods of plank exercises

Descriptions	Exercises
GP	General Plank exercise
GPA	General Plank exercise with Abdominal drawing-in maneuver
USP	Unstable Surface of the Plank
USPA	Unstable Surface of the Plank with Abominal drawing-in maneuver

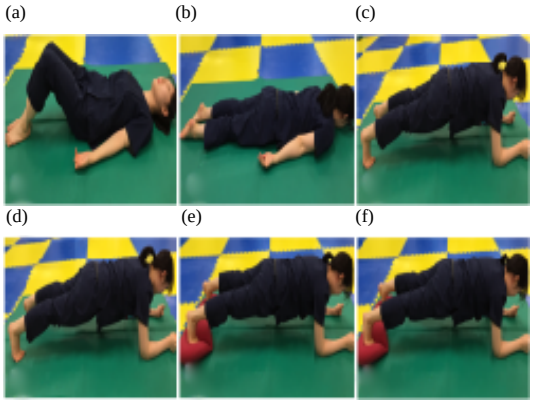

Fig. 4: a) TrA, IO, EO mesurement in resting position; b) MF mesurement in resting position; c) GP (General Plank exercise); d) GPA (General plank exercise with Abdominal drawing-in maneuver); e) USP (Unstable Surface of the Plank) and f) USPA (Unstable Surface of the Plank with Abominal drawing-in maneuver)

measurements were taken three times and average of them was used as data. To prevent muscle fatigue, two mediations were conducted every other day. In between mediations 10 min breaks were taken to prevent muscle fatigue. Also, to minimize studying effect of mediation order of experiment, orders were randomized.

Statistical analysis: About For data analysis, IBM SPSS/PC Ver. 22.0 for windows program was used. Shapiro-Wilk was performed for regularity examination and it satisfied regularity examination. During breaks and each plank exercise for the comparison regarding thickness change of transverse abdominis, internal abdominal oblique, external abdominal oblique and multifidus, repeated measure one way repeated ANOVA was used and for variable difference, Bonferroni method was used as post-hoc analysis. Statistical significance was set to be $p<0.05$.

RESULTS AND DISCUSSION

The thickness of TrA, IO, EO and MF was compared before the intervention and after each interventions. As a result of the post hoc test, there were significant difference of transverse abdominis, internal oblique,

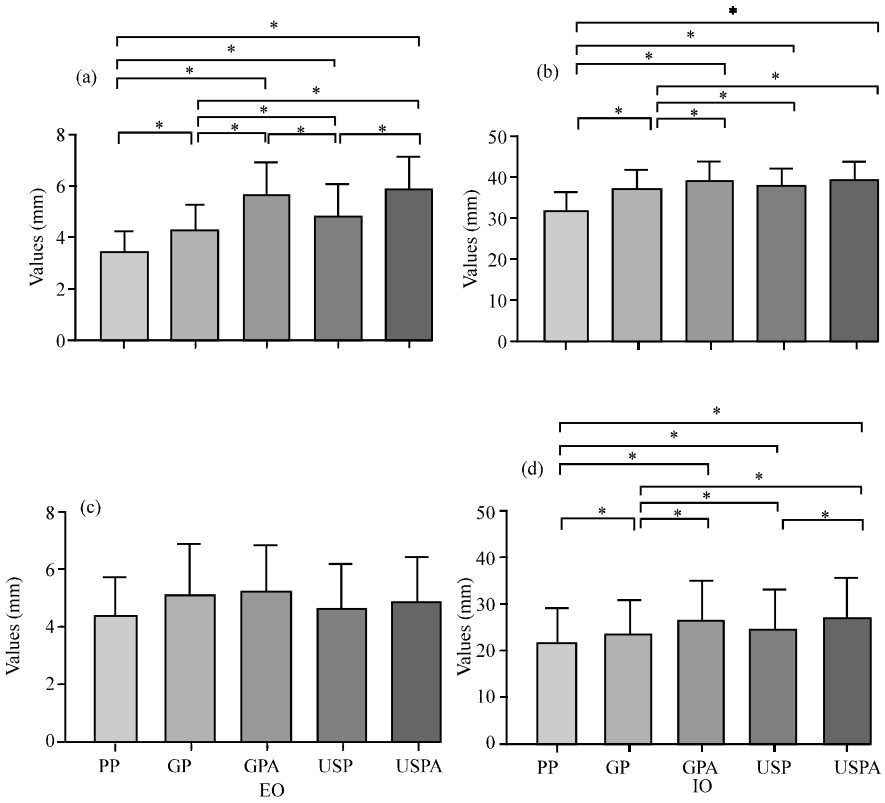

Fig. 5: a) TrA thickness compared to resting position and each plank exercises; b) IO thickness compared to resting position and each plank exercises; c) EO TrA thickness compared to resting position and each plank exercises and d) MF thickness compared to resting position and each plank exercises

Table 3: The comparisons of muscles thickness during Plank exercises (Units: mm) (n = 30)

Exercises muscles	PP	GP	GPA	USP	USPA	F-values
TrA	3.43±0.80a	4.26±1.03	5.66±1.22	4.83±1.17	5.86±1.24	62.37*
IO	6.76±2.03	7.13±2.12	8.01±2.47	7.43±2.49	8.25±2.50	18.05*
EO	4.54±1.23	5.16±1.81	5.27±1.64	4.68±1.57	4.69±1.52	2.107
MF	32.21±4.94	37.65±4.91	39.53±4.88	38.51±4.91	39.81±4.83	13.00*

*p<.05, amean ± standard deviation PP: Pre-Plank, GP: General plank, GPA: General Plank with ADIM,USP: Unstable Surface of the Plank, USPA: Unstable Surface of the Plank with ADIM

multifidus on both of PP and each plank exercise and between GP and GPA, GP and USPA, GPA and UP and UP and USPA significant differences were shown. But for External oblique, there was not significant difference ($p>0.05$) in Fig. 5.

For transverse abdominis, both on PP and each plank exercise, there was significant difference ($p<0.05$) and between GP and GPA, GP and USP, GP and USPA, GPA and USP and USP and USPA significant differences were shown ($p<0.05$) Table 5. For Internal abdominal oblique, both on PP and each plank exercise, there was significant difference ($p<0.05$) and between GP and GPA, GP and USPA, GPA and USP and USP and USPA significant differences were shown ($p<0.05$) for multifidus, both on PP and each plank exercise, there was significant difference ($p<0.05$) and between GP and GPA, GP and USPA significant differences were shown ($p<0.05$) in Table 3.

This research compared influence on trunk stabilization during plank exercise with abdominal drawing-in added on unstable surface by comparing the thickness of transverse abdominis, external abdominal oblique, internal abdominal oblique and multifidus. As a result, there was more statistical significant increase with thickness of transverse abdominis, internal abdominal oblique and multifidus during plank exercise than break. Rather than during GP during GPA, USP and USPA, thickness of transverse abdominis and internal abdominal oblique was significantly increased. During USP, increase of thickness of abdominis and internal abdominal oblique

is consistent with previous research suggesting that plank exercise on unstable surface had more increase of muscle activity than it on stable surface (Do and Yoo, 2015; Czaprowski *et al*., 2014; Escamilla *et al*., 2010; McGill, 2007; Akuthota and Nadler, 2004). However, only in between GP and GPA and GP and UPSA, multifidus showed significant difference. According to the previous research, it seems to be this result came out due to the fact that plank exercise mainly activates abdominal core muscles and multifidus is not the main muscle (Palmer *et al*., 2015; Coldron *et al*., 2008; Hodges and Richardson, 1997a, b) Additionally, the result of this research did not show significant difference of external abdominal oblique during plank exercise which shows that plank exercise activates core muscle rather than superficial muscles and external abdominal oblique was not acting as superficial muscle (O'Sullivan *et al*., 2003). In the comparison of each plank exercise, during GPA and USPA, thickness of transverse abdominis and internal abdominal oblique were majorly increased.

Regarding this, the reason significant difference on thickness of muscle is believed to be that abdominal drawing-in method pulls the abdominal wall inward which contracts only transverse abdominis and internal abdominal oblique and increase the abdominal pressure, resulting the waist stabilization training is performed effectively. Kwon referred that abdominal drawing-in method with real time ultrasonic wave feedback increase the activity of transverse abdominis while activity of external abdominal oblique. Also, Hodges and Richardson (1997a, b) reported that during ADIM rather than general waist stabilization exercise was performed, it is more effective to increase the thickness of transverse abdominis and internal abdominal oblique. Therefore, during the plank exercise on stable and unstable exercise when abdominal drawing-in method is added, thickness of transverse abdominis and internal abdominal oblique and thickness of external abdominal oblique decreases which is consistent with the result of the experiment. In other words, it seems to be it leads simultaneous contraction of muscles, core stabilization is relatively more activated, resulting stabilization of trunk rather than during the general plank. Therefore, transverse abdominis and internal abdominal oblique which are involved with core stabilizing muscle were activated and it seems to be that plank exercise on stable and unstable surface with abdominal drawing-in method is effective plank exercise in this research. Also, it is suggested that it is effective to stabilize the trunk with simultaneous contraction of abdominal and back muscles due to the fact that during GPA and USPA, multifidus thickness was increased as well.

Next, on the comparison of muscle activity with other mediation added to general plank exercise, there was significant difference on plank exercise with mediation of unstable surface and plank exercise with ADIM regarding TrA and GP but between GPA and USP, only TrA had significant difference and GPA was more effective. This shows that TrA is main expiration muscle on ADIM when it is compared to IO.

There are electromyography and ultrasonography measurement for measuring the activity of core muscles. Another way to measure the core muscle with electromyography may be crossed with other superficial muscles, resulting inaccurate measurement without differentiating activity of each muscle (Teyhen *et al*., 2007), ultrasonography with better reliability on thickness evaluation is used for measuring activity of core muscles (Hodges *et al*., 2003; Hodges and Richardson, 1997a, b).

Hides *et al*. (1994) referred that ultrasonic wave was used to evaluate atrophy and hypertrophy directly and there are a lot of researches conducted with electromyography during plank, yet not a lot of them with ultrasonography. Therefore, in this research, ultrasonography was used to measure the change of thickness of transverse abdominis, internal abdominal oblique and multifidus which are core muscles that play role of stabilization and it of external abdominal oblique, a superficial muscle.

In this research, there are a few limitations. First of all, subjects of this research were healthy male and female who are in 20s to evaluate the muscle activity of core stability muscle of trunk. Therefore, it cannot be generalized to all age group. Also, there were not many test subjects, thus, it will have difficulties to assume that this is the result of this age group. Second, applying balance pad is not the most effective plank exercise on unstable surface. This research suggests additional research on plank exercise with abdominal drawing-in method on unstable surface with various types of balance pad such as suspension and gym balls. Thirdly, in this research thickness of transverse abdominis, internal abdominal oblique, external abdominal oblique and multifidus were measured on third expiration of each test subject, however, they are not precisely same, resulting another limitation of this research. Lastly, this research was not long-term research but it is comparison of measurement of muscle thickness with temporary positions, a future research with muscle thickness activity change through long-term core stabilization training.

CONCLUSION

The results of this study indicate that the thickness and activity of core muscles in GPA and USPA increased more than in other interventions. Therefore, the plank exercise combined ADIM is expected more effective for stabilization of trunk muscles.

REFERENCES

Akuthota, V. and S.F. Nadler, 2004. Core strengthening. Arch. Phys. Med. Rehabil., 85: 86-92.

Akuthota, V., A. Ferreiro, T. Moore and M. Fredericson, 2008. Core stability exercise principles. Current Sports Med. Rep., 7: 39-44.

Brill, P., W.B. Peggy and S.C. Gerald, 2002. The Core Programme: Fifteen Minutes Exercise a Day that Can Change Your Life. 1st Edn., Bantam Books, New York, USA., ISBN:9780091882419, Pages: 256.

Carter, J.M., W.C. Beam, S.G. McMahan, M.L. Barr and L.E. Brown, 2006. The effects of stability ball training on spinal stability in sedentary individuals. J. Strength Conditioning Res., 20: 429-435.

Coldron, Y., M.J. Stokes, D.J. Newham and K. Cook, 2008. Postpartum characteristics of rectus abdominis on ultrasound imaging. Manual Ther., 13: 112-121.

Critchley, D., 2002. Instructing pelvic floor contraction facilitates transversus abdominis thickness increase during low-abdominal hollowing. Physiother. Res. Intl., 7: 65-75.

Czaprowski, D., A. Afeltowicz, A. Gêbicka, P. Pawlowska and A. Kedra *et al*., 2014. Abdominal muscle EMG-activity during bridge exercises on stable and unstable surfaces. Phys. Ther. Sport, 15: 162-168.

Do, Y.C. and W.G. Yoo, 2015. Comparison of the thicknesses of the transversus abdominis and internal abdominal obliques during plank exercises on different support surfaces. J. Phys. Ther. Sci., 27: 169-170.

Ekstrom, R.A., R.A. Donatelli and K.C. Carp, 2007. Electromyographic analysis of core trunk, hip and thigh muscles during 9 rehabilitation exercises. J. Orthopaedic Sports Phys. Ther., 37: 754-762.

Escamilla, R.F., C. Lewis, D. Bell, G. Bramblet and J. Daffron *et al*., 2010. Core muscle activation during Swiss ball and traditional abdominal exercises. J. Orthopaedic Sports Phys. Ther., 40: 265-276.

Hides, J.A., M.J. Stokes, M.J.G.A. Saide, G.A. Jull and D.H. Cooper, 1994. Evidence of lumbar multifidus muscle wasting ipsilateral to symptoms in patients with acute-subacute low back pain. Spine, 19: 165-172.

Hodges, P.W. and C.A. Richardson, 1997a. Contraction of the abdominal muscles associated with movement of the lower limb. Phys. Ther., 77: 132-142.

Hodges, P.W. and C.A. Richardson, 1997b. Feedforward contraction of transversus abdominis is not influenced by the direction of arm movement. Exp. Brain Res., 114: 362-370.

Hodges, P.W., L.H.M. Pengel, R.D. Herbert and S.C. Gandevia, 2003. Measurement of muscle contraction with ultrasound imaging. Muscle Nerve, 27: 682-692.

Imai, A., K. Kaneoka, Y. Okubo, I. Shiina and M. Tatsumura *et al*., 2010. Trunk muscle activity during lumbar stabilization exercises on both a stable and unstable surface. J. Orthopaedic Sports Phys. Ther., 40: 369-375.

Jackie, W.L., 2007. Ultrasound Imaging for Rehabilitation of the Lumbopelvic Region a Clinical Approach. Elsevier, Amsterdam, Netherlands, ISBN:13-978-0-443-06856-0, Pages: 183.

Kwon, N.H., H.O. Lee and D.J. Park, 2011. The use of real-time ultrasound imaging for feedback during abdominal hollowing. J. Korean Soc. Phys. Med., 6: 303-310.

Marshall, P.W. and B.A. Murphy, 2005. Core stability exercises on and off a Swiss ball. Arch. Phys. Med. Rehabil., 86: 242-249.

McGill, S.M., 2007. Low Back Disorders: Evidenced-Based Prevention and Rehabilitation. 2nd Edn., Human Kinetics Publishers, Champaign, Illinois, ISBN-13:978-0-7360-6692, Pages: 315.

Mok, N.W., E.W. Yeung, J.C. Cho, S.C. Hui and K.C. Liu *et al*., 2015. Core muscle activity during suspension exercises. J. Sci. Med. Sport, 18: 189-194.

Oh, J.S., H.S. Cynn, J.H. Won, O.Y. Kwon and C.H. Yi, 2007. Effects of performing an abdominal drawing-in maneuver during prone hip extension exercises on hip and back extensor muscle activity and amount of anterior pelvic tilt. J. Orthopaedic Sports Phys. Ther., 37: 320-324.

O'Sullivan, P.B., A. Burnett, A.N. Floyd, K. Gadsdon and J. Logiudice *et al*., 2003. Lumbar repositioning deficit in a specific low back pain population. Spine, 28: 1074-1079.

Palmer, T., T.L. Uhl, D. Howell, T.E. Hewett and K. Viele *et al*., 2015. Sport-specific training targeting the proximal segments and throwing velocity in collegiate throwing athletes. J. Athletic Training, 50: 567-577.

Radziszewski, K.R., 2007. Physical exercise in treatment of patients with lumbar discopathy. Ortopedia Traumatologia Rehabil., 9: 98-106.

Reeve, A. and A. Dilley, 2009. Effects of posture on the thickness of transversus abdominis in pain-free subjects. Manual Ther., 14: 679-684.

Richardson, C.A. and G.A. Jull, 1995. Muscle control pain control: What exercises would you prescribe?. Manual Ther., 1: 2-10.

Teyhen, D.S., N.W. Gill, J.L. Whittaker, S.M. Henry and J.A. Hides *et al*., 2007. Rehabilitative ultrasound imaging of the abdominal muscles. J. Orthopaedic Sports Phys. Ther., 37: 450-466.

Walker, M.L., J.M. Rothstein, S.D. Finucane and R.L. Lamb, 1987. Relationships between lumbar lordosis, pelvic tilt and abdominal muscle performance. Phys. Ther., 67: 512-516.

Wallwork, T.L., W.R. Stanton, M. Freke and J.A. Hides, 2009. The effect of chronic low back pain on size and contraction of the lumbar multifidus muscle. Manual Ther., 14: 496-500.

Willson, J.D., C.P. Dougherty, M.L. Ireland and I.M. Davis, 2005. Core stability and its relationship to lower extremity function and injury. J. Am. Acad. Orthopaedic Surgeons, 13: 316-325.