EFFECTIVENESS OF CORE STABILITY TRAINING AND DYNAMIC STRETCHING IN REHABILITATION OF CHRONIC LOW BACK PAIN PATIENTS

Ebby Waqqash Mohamad Chan[1*], Rahmat Adnan[1], and Ridzuan Azmi[2]

[1]Faculty of Sports Science and Recreation, Universiti Teknologi MARA Shah Alam, Malaysia
[2]Rehabilitation Unit, Armed Forces Hospital Tuanku Mizan, Kuala Lumpur, Malaysia

[*]Email: ebbywaqqash@hotmail.com
(Received 28 December 2017; accepted 18 July 2018; published online 17 January 2019)

To cite this article: *Mohamad Chan, E. W., Adnan, R., & Azmi, R. (2019). Effectiveness of core stability training and dynamic stretching in rehabilitation of chronic low back pain patients. Malaysian Journal of Movement, Health & Exercise, 8(1), 1-13.* https://doi.org/10.15282/mohe.v8i1.210
Link to this article: https://doi.org/10.15282/mohe.v8i1.210

Abstract

To evaluate the effectiveness of core stability training and dynamic stretching on thoracolumbar range of motion (ROM), pain level and functional disability among chronic low back pain patients. Forty-three participants aged from 19-67 years old with the primary complaint of low back pain of more than 12 weeks' duration were assigned to three groups: core stability (CS) (n=17), dynamic stretching (DS) (n=16) and control (n=12). All participants received regular thermotherapy and electrotherapy from the hospital rehabilitation unit. The CS group and DS groups were assigned with additional training, namely core stability training and dynamic stretching training programs for the respective groups. No additional training was given to the control group. The participants' thoracolumbar range of motion (ROM), pain level and functional disability were tested over four different testing periods (pre, acute, ongoing, post). The current study shows both the CS group and DS group show significant improvement ($p<0.05$) in thoracolumbar ROM (CS group; $\eta_p^2 = 0.50$, CS group; $\eta_p^2 = 0.66$), pain level (CS group; $\eta_p^2 = 0.85$, CS group; $\eta_p^2 = 0.81$), and functional disability (CS group; $\eta_p^2 = 0.65$, CS group; $\eta_p^2 = 0.82$). In summary, both core stability exercise and dynamic stretching are effective in improving thoracolumbar ROM, pain-level, functional disability among chronic low back pain patients.

Keywords: Low back pain, core stability, stretching

Introduction

Chronic low back pain (CLBP) is one of the most prevalent causes of disability and morbidity in our society (Ferreira et al., 2007; Gooch, Pracht, & Borenstein, 2017; Mohseni-Bandpei, Rahmani, Behtash, & Karimloo, 2011). CLBP affects up to 85% of the population at some point in their lives. The vast majority (90%) will improve over a three-month period, but nearly 50% will experience at least one recurrent episode (Brukner & Khan, 2007).

Rehabilitation therapies for CLBP have emerged over time. Core stability training is the basic and fundamental component of many comprehensive functional rehabilitation programs (Prentice, 2011; Stuber, Bruno, Sajko, & Hayden, 2014; You, Kim, Oh, & Chon, 2014). In the late 1990s, core stability training was created based upon findings from large number of studies which demonstrated the significance of trunk control in neuromuscular reorganization in managing back pain (Lederman, 2010). Core stability training programs are designed to help an individual to gain functional strength, neuromuscular control and the endurance of core muscles (Prentice, 2011; Standaert, Weinstein, & Rumpeltes, 2008; Waqqash, Adnan, Yusof, Sulaiman, & Ismail, 2014). Retraining the core muscles through core stability training will enable an individual with CLBP to maintain the spine and pelvis in the most comfortable and acceptable mechanical position, controlling the forces of repetitive micro trauma and protecting the structures of the back from further damage (Prentice, 2011). Norris and Matthews (2008) reported core stability training helps improve the level of pain and functional impairment in 89% of patients suffering from CLBP. Bronfort et al. (2011) also reported similar findings in which supervised core stability training improves pain severity, functional disability, and general health status after 12 weeks of treatment.

Muscular stretching is another physical therapy treatment increasingly used in rehabilitation programs for CLBP (Lawand et al., 2015; Poiraudeau & Revel, 2000). According to Brukner and Khan (2007), specific muscle tightness (i.e. erector spinae, psoas, iliotibial band, hip external rotators, hamstrings, and gastrocnemius) is commonly found in association with low back pain. Tightness of these specific muscles affects the biomechanics of the lumbar spine, diminishing the shock absorbing capacity of the lumbar segments and increasing compression force on the lumbar spine. Muscular stretching programs are designed to progressively stretch the muscle groups which are assumed to be too tight and improve the body biomechanics (Prentice, 2011). Cleland, Childs, Palmer, and Eberhart (2006) investigated the effects of slump stretching on pain (using numeric pain rating scale), centralization symptoms (using body diagram) and functional disability (Oswestry disability index) among non-radicular low back pain patients. Patients were revealed to experience significant improvements in pain (NRPS=0.93 points, $P= 0.001$) and disability (ODI= 9.7 points, $P < 0.001$) and centralization of symptoms ($P<0.01$) after 3 weeks (total of 6 sessions) of slump stretching.

Currently, there are few evidence on the effects of muscular stretching protocols for rehabilitation particularly CLBP patients (Alter, 2004; Poiraudeau & Revel, 2000). Dynamic stretching is a stretching protocol which has been widely used to improve sports performance (Alter, 2004). Dynamic stretching techniques emulate sport-specific movements by using active controlled movements without bouncing within a normal ROM. The movement pattern is similar to sport-specific warm up but in lower intensity (Longo, 2009; Nelson & Kokkonen, 2007). Recent studies have shown that dynamic stretching improves static and dynamic flexibility (Samukawa, Hattori, Sugama, & Takeda, 2011; Silveira, Sayers, & Waddington, 2010), jumping height and power (Jaggers, 2006), running economy (Henry, 2010), and anaerobic activities (Estes, 2008). The aim of this study is to investigate the effectiveness of core stability training and dynamic stretching on thoracolumbar range of motion (ROM), pain level and functional disability in CLBP patients.

Material and Method

Subjects

Forty-three (n=43) participants aged from 19 to 67 years old with prior complain of low back pain for more than 12 weeks were recruited from Rehabilitation Unit, Armed Forces Hospital Tuanku Mizan. Participants were all screened by the hospital physician with the diagnosis of CLBP. Any serious diagnosis such as spondylolisthesis (slip of low back vertebra) and cauda equine syndrome (swelling of the end nerves of the spinal cord) were excluded from this study. Participants taking painkiller within three months were also excluded.

Ethical Clearance

Research Management Institute, Universiti Teknologi MARA granted ethical approval for this study (reference number: 600-RMI 5/1/6) and all participants provided written informed consent prior to their participation.

Treatment Program

Participants were randomly assigned into three groups: core stability (CS) (n=17), dynamic stretching (DS) (n=16) and control (n=12). All participants received regular thermotherapy (hydrocollator heat pack) and electrotherapy (interferential therapy) from the hospital rehabilitation unit for 6 weeks (twice per week) and 30 min/session. The CS group and DS group were assigned additional 20-minute training: core stability training and dynamic stretching training programs for respective groups. No additional training was given to the control group.

The core stability training includes squats, lunges, draw-in manoeuvre, crunches, 2-legged bridge, plank, plank with alternate leg lift, and alternate arm opposing leg lift. The eight exercises were performed for 2 sets at 10-15 repetitions. The core stability training routine was adapted from Prentice (2011). The dynamic stretching regime includes front kick, back kick, side leg swings, outer leg chops, slump stretch, cat and camel stretch, child pose stretch, and overhead lat stretch. The eight stretching routines were also performed for 2 sets at 10-15 repetitions. The dynamic stretching routine was adapted from Cleland et al. (2006) and Nelson and Kokkonen (2006). In order to blind the participants to their treatment allocation, the CS group and DS group received their treatments on different days.

Instruments

The outcome measures in this study were thoracolumbar range of motion (ROM), pain level, and functional disability.

Thoracolumbar ROM were operationalized in this study as the motion extent (flexion, extension and rotation) of the participants' trunk. The trunk flexion, extension and rotation are the most affected ROM among patients with chronic low back pain (Karnath, 2003). The instrument used to measure thoracolumbar ROM is the goniometer, a large protractor with measurements in degrees. According to Gogia, Braatz, Rose and Norton (1986), goniometric measurements have high validity (r = 0.97-0.98; ICC = 0.98-0.99) and reliability (r = 0.98; ICC = 0.99) for trunk motion. In this study, the participants thoracolumbar were measured three times with the best score of ROM as the final outcome.

The participants low back pain level was measured using numeric pain rating scale (NPRS), which is an 11-point scale ranging from 0-10. A 0 signifies "no pain" and a 10 indicates "the most intense pain imaginable". The scale continuum is as follows: 0 indicates "no pain", 5, "moderate pain" and 10, "the most intense pain imaginable". Participants verbally selected a value ranging from 0-10 that is most in line with the intensity of pain they currently experienced. Herr, Spratt and Richardson (2004) reported that the concurrent validity between NPRS and other scales are high; Visual Analogue scale (r=0.86), verbal descriptor scale (r = 0.88), 21-point Numeric scale (r=0.87) and faces pain scale (r=0.80).

The Oswestry disability index (ODI) is a self-administered questionnaire designed to evaluate level of function (disability) in activities of daily living for individuals rehabilitating for low back pain. The ODI consists of 10 sections with a scale ranging from 0 to 5, whereby the 5 represents the greatest disability. The total sum of the score is then multiplied with hundred and expressed as percentage. The ODI showed good construct validity at measuring disability cause by low back pain because it is consistent with other standard outcome measures which includes Low back outcome score, the Manniche Scale, the Aberdeen score, and The Curtin Scale (Vianin, 2008). In addition, the test-retest reliability for the ODI is high with ranges r=0.83 to r=0.99 which vary based on the time interval between each measurements (Fairbank & Pynsent, 2000; Vianin, 2008).

The participants ODI scores were converted into percentage using the formula below:
Participants score / (50) x 100 = %
The participants % score will be categorized using the scoring below:
0 % to 20%: minimal disability
21% to 40 %: moderate disability
41% to 50%: severe disability
61% to 80%: crippled
81% to 100%: bed-bound

Data collection procedure:

All equipment was calibrated and confirmed to be in good working condition. The moving and stationary arms of the goniometer were ensured not to be loose because this can affect the reliability and validity of the data collected. Test-retest reliability of all the equipment was performed by the examiner before the test stage to ensure that the data collected was consistent throughout the test stage. Participants were also instructed to read and understand the PAR-Q and sign the informed consent form prior to the test.

There were altogether four test stages: pretest (prior 1^{st} session), acute test (after 1^{st} session), ongoing test (after 6^{th} session), and posttest (after the last session) throughout the 12 sessions. Thoracolumbar range of motion (ROM), pain level, and functional disability were measured in the tests. The functional disability was not measured during acute test (after 1^{st} session) because it is not possible to assess functional disability acutely after an intervention. The first outcome measures evaluated was the thoracolumbar ROM. The thoracolumbar ROM was referring to the flexion, extension and rotation of the participants' trunk. The thoracolumbar ROM was measured using the JAMAR goniometer. The thoracolumbar ROM was measured for three trials. The best of the three trials was recorded. The second outcome measure evaluated was the pain level. After the goniometric measurements, each participant was given 5 to 10 minutes to rest. The purpose of the rest period was to ensure that participants did not perceive the pain which may be caused after performing multiple trunk motions during the goniometric measurements. After participants are relaxed and in comfortable state, the examiner told the participant to rate their pain level from a scale of 0 to 10 and wrote it down in the form provided. The third and final outcome measures evaluated was the functional disability. The functional disability was assessed using the Oswestry disability index (ODI) questionnaire. The participants were given 10 to 15 minutes to answer the ODI questionnaire. The examiner was prompt to answer any questions asked by the participants regarding the ODI questionnaire.

Data analysis

IBM Statistical Package for the Social Sciences (SPSS version 20.0) were used in the current study to run Mixed Design ANOVA - 3 Group (CS group, DS group, Control group) x 4 testing periods (Pre, Acute, On-going, Post) ANOVA with repeated measures. The dependent variables which were tested were thoracolumbar ROM, pain level and functional disability. A separate repeated measure analyses for each level in the grouping factor was administered to assess the significance of the treatment main effect. The alpha level required for significance level of all tests was set at $p<0.05$.

Results

Demographic information

Forty-three military personnel diagnosed with chronic low back pain (CLBP) participated in this study. The mean age ± standard deviation (SD) of age was 37.05±13.17 years; weight 72.14±14.35 kg; height 1.66±0.08 m; and body mass index (BMI) 26.12±4.6 kg/m^2. The results from Shapiro Wilk normality test indicated that all the variables did not deviate significantly from a normal distribution ($P>.05$). Based upon the normality test conducted, parametric methods were applied for the inferential statistics.

Thoracolumbar ROM

The current study shows significant interaction in thoracolumbar ROM (flexion, extension, right rotation, left rotation) between 4 tests (pre, acute, ongoing, post) and treatment (CS group, DS group, control); F (20, 36) = 4.03, $p < 0.05$; ηp2 = 0.88. The post-hoc main effect test revealed significant improvements in thoracolumbar ROM ($p <0.05$) in CS group (ηp2 = 0.66) and DS group (ηp2 0.50). However, no significant improvements in thoracolumbar ROM ($p > 0.05$) were found among the control group (ηp2 = 0.14). The current study shows both the CS group and DS group were effective in improving the thoracolumbar ROM through twelve sessions. The graphical representations of thoracolumbar ROM of CS group, DS group and control group across pre, acute, ongoing and post testing are shown in figure 1.

Pain level and Functional disability

Table 1 shows the mean ± SD of pain level and functional disability for CS group, DS group and control group. Pain level shows significant interaction between test (pre, acute, ongoing, post) and group (CS group, DS group, control group); F (6, 52) = 5.46, $p <0.05$; Wilk's Λ = 0.37, $\eta_p^2 = 0.40$. The post-hoc main effect test reveals that CS group (η_p^2 0.85) and DS group ($\eta_p^2 = 0.81$) experienced in a significant reduction in pain level ($p< 0.05$). Nevertheless, no significant changes in pain level ($P>0.05$) was found among the control group ($\eta_p^2 = 0.31$). This shows that dynamic stretching and core stability training were both effective in reducing pain level after completing all twelve sessions.

In addition, functional disability also revealed significant interaction between test (pre, ongoing, post) and group (CS group, DS group, control), F (4, 54) = 5.58, $p < 0.05$; $\eta_p^2 = 0.30$. The post-hoc main effect test shows that CS group (η_p^2=0.65) and DS group ($\eta_p^2 = 0.82$) was significant in improving functional disability. The findings show that after twelve sessions, both core stability training and dynamic stretching helped to significantly improve activities of daily living (ADLs) by reducing the Oswestry disability index (ODI) score.

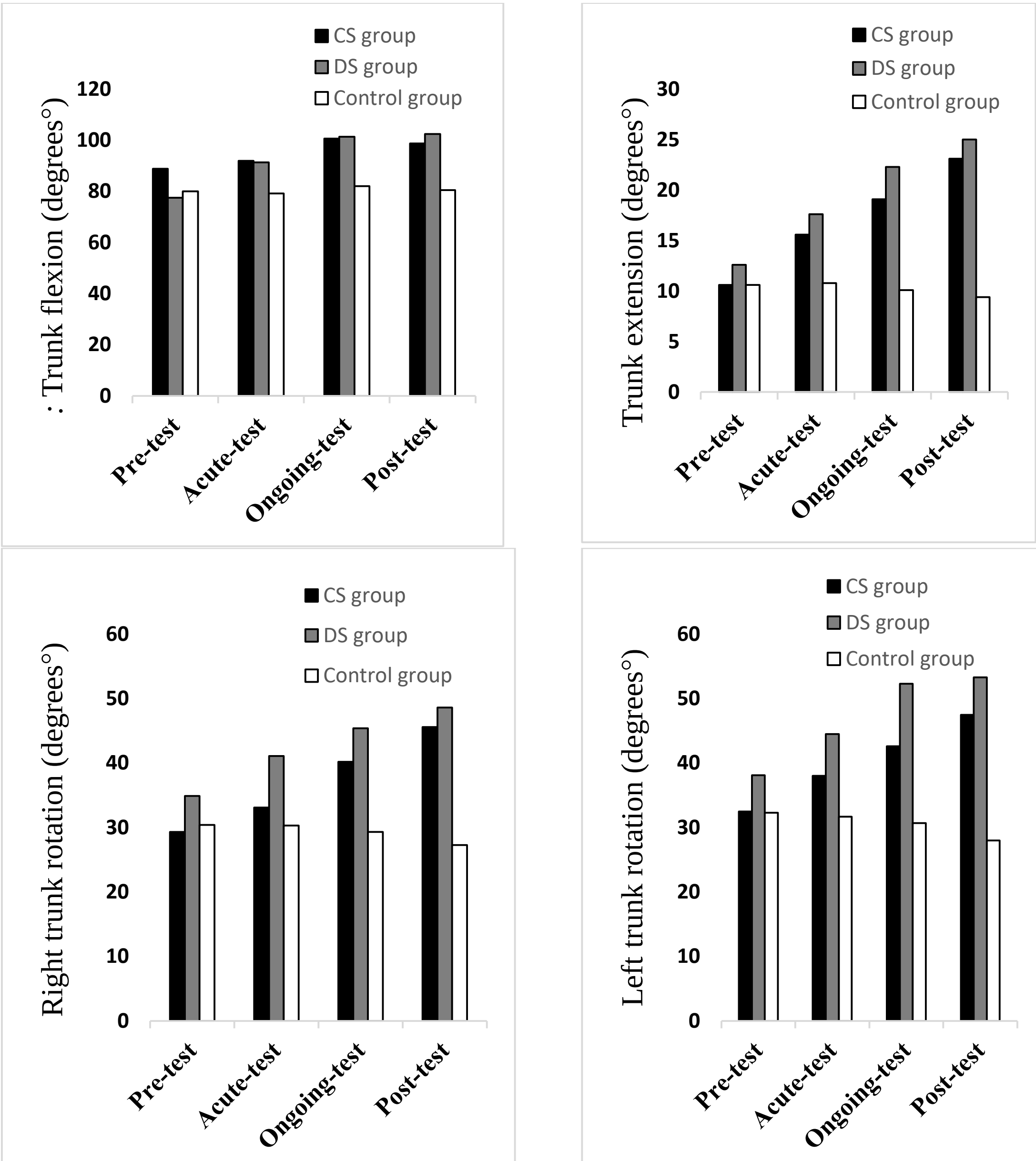

Figure 1: Thoracolumbar range of motion (ROM) of core stability (CS) group, dynamic stretching (DS) group and control group across pre, acute, ongoing and post testing.

Table 1: Numeric pain rating scale (NPRS) & Oswestry Disability Index (ODI) Means and Standard Deviations

Test	Group	NRPS (0-10) Mean (SD)	ODI (%) Mean (SD)
Pretest	CS group	5.90 (1.10)	41.6 (9.96)
	DS group	5.20 (1.23)	40.8 (8.95)
	Control group	4.90 (1.66)	41.3 (12.1)
Acute test	CS group	5.10 (0.88)	-
	DS group	4.20 (1.93)	-
	Control group	4.70 (1.32)	-
Ongoing test	CS group	4.40 (0.84)	27.4 (5.92)
	DS group	3.30 (1.52)	21.9 (9.98)
	Control group	5.20 (1.93)	43.8 (13.4)
Post test	CS group	3.30 (0.95)	20.7 (6.93)
	DS group	2.60 (0.71)	17.8 (6.55)
	Control group	5.5 (1.84)	46.5 (13.13)

Discussion

The purpose of the current study was to evaluate the effectiveness of core stability training and dynamic stretching on thoracolumbar range of motion (ROM), pain level and functional disability in chronic low back pain patients. Both the core stability group and dynamic stretching group demonstrated improvement on thoracolumbar ROM, pain-level and functional disability.

It is not surprising to see the increase thoracolumbar ROM among the dynamic stretching group after the twelve sessions. According to Nelson and Kokkonen (2007), the dynamic stretching employs the Sherrington's law of reciprocal inhibition and contraction. Sherrington's law states that when a muscle on one side of a joint contracted, the muscle on the opposite side sends neurological signals to relax/stretches (Alter, 2004). Recent studies have shown that dynamic stretching is the superior stretching technique to improve static and dynamic flexibility (Samukawa et al., 2011; Silveira et al., 2010). According to Thakur (2009), a lack of flexibility will lead to muscle and joint stiffness and poor body posture. Kujala, Salminen, Taimela, Oksanen, and Jaakkola (1992) also reported the aggregate of lifetime low back pain history of low back pain is greatly linked with the tightness of hip flexor. The hip flexor muscle tightness causes anterior pelvic tilt, which means the spine has increased lordotic curve (inward curve of the low back), causing unnecessary stress to the bones, nerves, ligaments, and muscles attach to the vertebrae (Brukner & Khan, 2007). Numerous studies suggest that adequate flexibility and stretching may help reduce the risk or severity of low back pain (Brukner & Khan, 2007; Cleland et al., 2006; França, Burke, Caffaro, Ramos, & Marques, 2012; Houglum, 2005; Nelson & Kokkonen, 2007; Prentice, 2011). The main purpose of a stretching program is to promote adaptation in the increase of range of motion (ROM) (Nelson & Kokkonen, 2007). The current study also revealed that core stability training is also effective in improving the thoracolumbar ROM. The present findings were similar to Baard, Pietersen, and Rensburg (2011) who discovered that core stability training helps increase the flexibility of lumbo-pelvic-hip complex and the hamstring muscles. It is hypothesized the improvement of ROM is because the core musculature has gained sufficient coordination and strength to move through the full ROM painfree (Prentice, 2011). In addition, exercise promote local blood flow to active muscles which contributes to generation of additional heat, which provides enhanced muscle elasticity and facilitates the increase range of motion of the specific muscles (Prentice, 2011).

Pain is the patients' subjective feeling which can be described as an ache, spasms, sharp, dull, and colicky (Karnath, 2003). The present outcomes show that both core stability and dynamic stretching reduces the pain after completing all 12 sessions. Devi, Kumar, Babu, and Ayyappan (2014) reported that stretching specific muscle groups (lower back muscle, hamstring and tensor fasciae latae) clinically showed significant effect in improving pain among community nurses with occupation related chronic low back pain. Rajaratnam et al. (2009) also discovered that stretching exercises in between prolong sitting were efficient in reducing participants' level of discomfort. According to Rajaratnam et al. (2009), stretching helps to disperse the intraneural edema, hence reestablishing the pressure gradients, relieving hypoxia and ultimately reducing pain.. Cleland et al. (2006) hypothesized that the possible mechanism for the greater pain relief in stretching can be associated with reduction of scar tissues of the neural structures and its associated connective tissue structures. The present study also revealed that core stability training are also effective in improving pain level. Chung, Lee, and Yoon (2013) also reported similar findings in which core stability training helps promote pain relief in low back pain patients.

It is common for some low back pain patients to only feel pain during performing simple daily tasks such as distance walking or gardening. The Oswestry disability index (ODI) was designed to evaluate level of functional disability in activities of daily living (ADLs) for individuals rehabilitating for low back pain (Fairbank & Pynsent, 2000). Overall both interventions (dynamic stretching and core stability training) improved the patients' functional disability. Research conducted by Chen, Wang, Chen, and Hu (2012) also discovered a similar finding, whereby the stretching program promotes moderate to high level of LBP relief and improvement on exercise self-efficacy (Chen et al., 2012). It is believed that patients' reduced functional disability is because of their reduced pain level (Areeudomwong et al., 2012). The theory that pain relief helps to reduced functional disability is also supported by other study. Devi et al. (2014) indicated that the improvement in pain and flexibility increases the working capacity of the community nurses; hence showing improvement in the community nurses' functional ability. Previous studies have also shown that core stability training is effective in improving CLBP patients' functional ability (Chung et al., 2013; França et al., 2012; Mohseni-Bandpei et al., 2011; Norris & Matthews, 2008). It is believed that the abdominal draw-in maneuver in core stability training can provide powerful biofeedback to emphasize integration of muscle control in stabilizing the spine during functional tasks (Areeudomwong et al., 2012).

This study has several limitations that needed to be addressed. Firstly, it is not ethically possible to propose for the control group to be inactive and received no treatment. Secondly, all participants involved in this study were asked not to use or do any other form of external rehabilitation besides from the treatment received at the hospital rehabilitation unit (i.e. ointment or rub to massage the low back); however, it was beyond the investigators' control if the participants did not comply with the instructions. Lastly, participants were military personnel and their occupation demands them to perform laborious activities such as heavy lifting of military equipment and intense physical training, which may have affected the treatment effects.

Conclusion

It is concluded that both core stability training and dynamic stretching have positive effects in improving thoracolumbar range of motion, pain level and functional ability to perform daily task. Further investigation is warranted using clinical measures such as electromyography (EMG) and ultrasound imaging scan to analyze the activation level or recruitment order of deep core muscles (i.e. multifidus and transverse abdominis).

References

Alter, J. M. (2004). *Science of Flexibility* (3rd ed.): Human Kinetics.

Areeudomwong, P., Puntumetakul, R., Jirarattanaphochai, K., Wanpen, S., Kanpittaya, J., Chatchawan, U., & Yamauchi, J. (2012). Core stabilization exercise improves pain intensity, functional disability and trunk muscle activity of patients with clinical lumbar instability: A pilot randomized controlled study. *Journal of Physical Therapy Science, 24*(10), 1007-1012. doi: 10.1589/jpts.24.1007

Baard, L. M., Pietersen, J., & Rensburg, V. J. S. (2011). Interventions for chronic low back pain: whole body vibration and spinal stabilisation. *South African Journal Of Sports Medicine, 23*(2), 35-39.

Bronfort, G., Maiers, M. J., Evans, R. L., Schulz, C. A., Bracha, Y., Svendsen, K. H., Grimm, R. H., Owens, E. F., Garvey, T. A., & Transfeldt, E. E. (2011). Supervised exercise, spinal manipulation, and home exercise for chronic low back pain: a randomized clinical trial. *The Spine Journal, 11*(7), 585-598. doi: http://dx.doi.org/10.1016/j.spinee.2011.01.036

Brukner, P., & Khan, K. (2007). *Clinical Sports Medicine* (Third ed.). Sydney: McGraw-Hill.

Chen, H. -M., Wang, H. -H., Chen, C. -H., & Hu, H. -M. (2012). Effectiveness of a stretching exercise program on low back pain and exercise self-efficacy among nurses in Taiwan: A randomized clinical trial. *Pain Management Nursing*(0). doi: http://dx.doi.org/10.1016/j.pmn.2012.10.003

Chung, S., Lee, J., & Yoon, J. (2013). Effects of stabilization exercise using a ball on mutifidus cross-sectional area in patients with chronic low back pain. *Journal of Sports Science and Medicine, 12*, 1-9.

Cleland, J. A., Childs, J. D., Palmer, J. A., & Eberhart, S. (2006). Slump stretching in the management of non-radicular low back pain: A pilot clinical trial. *Manual Therapy, 11*(4), 279-286. doi: http://dx.doi.org/10.1016/j.math.2005.07.002

Devi, Z. K., Kumar, S. N., Babu, K. B., & Ayyappan, R. V. (2014). Effectiveness of muscle stretching in occupation related chronic mechanical low back pain in community nurses - A single blind study. *International Journal of Physiotherapy and Research, 2*(1), 403-410.

Estes, T. M. (2008). *The effects of static and dynamic stretching protocols on a 30-second anaerobic bicycle test.* (M.S. 1461271), California University of Pennsylvania, United States -- Pennsylvania. Retrieved from http://search.proquest.com/docview/276099542?accountid=42518 ProQuest Dissertations & Theses (PQDT); ProQuest Dissertations & Theses (PQDT) database.

Fairbank, T. C. J., & Pynsent, B. P. (2000). The oswestry disability index. *The Journal of Spine*, *25*(22), 2940–2953.

Ferreira, M. L., Ferreira, P. H., Latimer, J., Herbert, R. D., Hodges, P. W., Jennings, M. D., Maher, C. G., & Refshauge, K. M. (2007). Comparison of general exercise, motor control exercise and spinal manipulative therapy for chronic low back pain: A randomized trial. *Pain, 131*(1–2), 31-37. doi: http://dx.doi.org/10.1016/j.pain.2006.12.008

França, F. R., Burke, T. N., Caffaro, R. R., Ramos, L. A., & Marques, A. P. (2012). Effects of muscular stretching and segmental stabilization on functional disability and pain in patients with chronic low back pain: A Randomized, controlled trial. *Journal of Manipulative and Physiological Therapeutics, 35*(4), 279-285. doi: http://dx.doi.org/10.1016/j.jmpt.2012.04.012

Gogia, P. P., Braatz, H. J., Rose, J. S., & Norton, J. B. (1986). Reliability and validity of goniometric measurements at the knee. *Journal of the American Physical Therapy Association and Royal Dutch Society for Physical Therapy*, 192-195.

Gooch, C. L., Pracht, E., & Borenstein, A. R. (2017). The burden of neurological disease in the United States: a summary report and call to action. *Annals of neurology, 81*(4), 479-484.

Henry, K. (2010). *The effects of three different stretching interventions on running economy in trained female athletes.* (Ph.D. 3414422), Texas Woman's University, United States -- Texas. Retrieved from http://search.proquest.com/docview/608981518?accountid=42518 ProQuest Dissertations & Theses (PQDT); ProQuest Dissertations & Theses (PQDT) database.

Herr, K. A., Spratt, K., & Richardson, G. (2004). Pain intensity assessment in older adults: use of experimental pain to compare psychometric properties and usability of selected pain scales with younger adults. *Clinical Journal of Pain*, *20*(4), 207-219.

Houglum, A. P. (2005). *Therapeutic exercise for musculoskeletal injuries* (Second ed.): Human Kinetics.

Jaggers, J. R. (2006). *The acute effects of dynamic and ballistic stretching on vertical jump height, force, and power*. (M.S. 1437350), University of Louisville, United States -- Kentucky. Retrieved from http://search.proquest.com/docview/305318527?accountid=42518 ProQuest Dissertations & Theses (PQDT); ProQuest Dissertations & Theses (PQDT) database.

Karnath, B. (2003). Clinical signs of low back pain. *Hospital Physician*, 39-44.

Kujala, U. M., Salminen, J. J., Taimela, S., Oksanen, A., & Jaakkola, L. (1992). Subject characteristics and low back pain in young athletes and nonathletes. *Medicine and Science in Sports and Exercise*, *24*(6), 627-632.

Lawand, P., Júnior, I. L., Jones, A., Sardim, C., Ribeiro, L. H., & Natour, J. (2015). Effect of a muscle stretching program using the global postural reeducation method for patients with chronic low back pain: A randomized controlled trial. *Joint Bone Spine, 82*(4), 272-277.

Lederman, E. (2010). The myth of core stability. *Journal of Bodywork & Movement Therapies, 14*, 84-98.

Longo, A. (2009). *Active isolated stretching: An investigation of the mechanical mechanisms.* (M.Sc. MR51908), Brock University (Canada), Canada. Retrieved from http://search.proquest.com/docview/305177548?accountid=42518 ProQuest Dissertations & Theses (PQDT); ProQuest Dissertations & Theses (PQDT) database.

Mohseni-Bandpei, M. A., Rahmani, N., Behtash, H., & Karimloo, M. (2011). The effect of pelvic floor muscle exercise on women with chronic non-specific low back pain. *Journal of Bodywork and Movement Therapies, 15*(1), 75-81. doi: http://dx.doi.org/10.1016/j.jbmt.2009.12.001

Nelson, G. A., & Kokkonen, J. (2007). *Stretching Anatomy*. United States of America: Human Kinetics.

Norris, C., & Matthews, M. (2008). The role of an integrated back stability program in patients with chronic low back pain. *Complementary Therapies in Clinical Practice*, *14*(4), 255-263. doi: http://dx.doi.org/10.1016/j.ctcp.2008.06.001

Poiraudeau, S., & Revel, M. (2000). Rehabilitation therapy in chronic low back pain. *Joint Bone Spine*, *67*(6), 582-587. doi: http://dx.doi.org/10.1016/S1297-319X(00)00210-4

Prentice, E. W. (2011). *Rehabilitation techniques for sports medicine and athletic training* (Fifth ed.): McGraw-Hill

Rajaratnam, B. S., Lam, C. M., Seah, H. H. S., Chee, W. S., Leung, Y. S. E., Ong, Y. J. L., & Kok, Y. Y. (2009). Can stretching exercises reduce your risks of experiencing low back pain? In C. Lim & J. H. Goh (Eds.), *13th International Conference on Biomedical Engineering* (Vol. 23, pp. 2114-2117): Springer Berlin Heidelberg.

Samukawa, M., Hattori, M., Sugama, N., & Takeda, N. (2011). The effects of dynamic stretching on plantar flexor muscle-tendon tissue properties. *Manual Therapy*, *16*(6), 618-622. doi: http://dx.doi.org/10.1016/j.math.2011.07.003

Silveira, G., Sayers, M., & Waddington, G. (2010). Effect of static and dynamic stretching on hamstring flexibility in the warm-up. *Journal of Science and Medicine in Sport, 12, Supplement 2*(0), e10-e11. doi: http://dx.doi.org/10.1016/j.jsams.2009.10.023

Standaert, C. J., Weinstein, S. M., & Rumpeltes, J. (2008). Evidence-informed management of chronic low back pain with lumbar stabilization exercises. *The Spine Journal*, *8*(1), 114-120. doi: http://dx.doi.org/10.1016/j.spinee.2007.10.015

Stuber, K. J., Bruno, P., Sajko, S., & Hayden, J. A. (2014). Core stability exercises for low back pain in athletes: a systematic review of the literature. *Clinical Journal of Sport Medicine*, *24*(6), 448-456.

Thakur, A. (2009). *Running economy: Acute effect of active isolated stretching*. (M.S. 1495982), Lamar University - Beaumont, United States -- Texas. Retrieved from http://search.proquest.com/docview/875564288?accountid=42518 ProQuest Dissertations & Theses (PQDT); ProQuest Dissertations & Theses (PQDT) database.

Vianin, M. (2008). Psychometric properties and clinical usefulness of the Oswestry Disability Index. *Journal of Chiropractic Medicine, 7*, 161–163.

Waqqash, E., Adnan, R., Yusof, S. M., Sulaiman, N., & Ismail, S. I. (2014). *Efficacy of core stability exercise and muscular stretching on chronic low-back pain.* Paper presented at the Proceedings of the International Colloquium on Sports Science, Exercise, Engineering and Technology 2014 (ICoSSEET 2014).

You, J. H., Kim, S.-Y., Oh, D. -W., & Chon, S. -C. (2014). The effect of a novel core stabilization technique on managing patients with chronic low back pain: A randomized, controlled, experimenter-blinded study. *Clinical rehabilitation*, *28*(5), 460-469.