The effects of strength exercise and walking on lumbar function, pain level, and body composition in chronic back pain patients

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The beneficial effects of a strength exercise program and a combined exercise program of strength training plus walking were examined in overweight with chronic back pain patients. The participants were randomly placed in the strength exercise group (SEG, n = 15), combined exercise group (CEG, n = 15), and control group (CG, n = 6). All subjects performed exercise twice per week, 50 min per session with a professional instructors for 12 weeks. In order to evaluate exercise intervention effects, lumbar function was measured by back strength and flexibility. Roland-Morris disability questionnaire (RMDQ) and visual analogue scale (VAS) were used to evaluate pain level. Fat and muscle mass were measured to compare body composition changes. All measurements were performed before and after 12 weeks of exercise program. Lumbar function: Back strength was significantly different over time, and significant time × group differences were found between SEG and CG, CEG and CG. Pain disorder degree: VAS showed a significant group difference, and significant time × group differences were shown between SEG and CG, and CEG and CG. Also, RMDG showed a significant difference between CEG and CG. Body composition: Fat mass was significantly different over time × group between SEG and CG. In conclusion, participating in strength and walking exercises were beneficial to improve lumbar function. Also, the combined exercise program was more effective for reducing pain levels than the strength exercise. Finally, fat mass was reduced in this study and this may play a possible role in the improvement of lumbar function and reduction in low back pain.

Keywords: Back pain, Walking exercise, Strength exercise

INTRODUCTION

Back pain is defined as overall pain from the second lumbar vertebra to the sacroiliac joints, and is a common lifetime health disorder (Hanney et al., 2016). In general, up to 84% of the general population report at least one episode of low back pain in their lifetime (Hoy et al., 2012), and it will resolve within 2 to 4 weeks. However, recurrent episode have been reported as 25% (Smith et al., 2013). Therefore, chronic back pain patients participate in very limited physical activity with limited usage of muscles, resulting in reduction and atrophy. Back pain is classified as (a) acute pain i.e. pain lasting less than 6 weeks; (b) subacute pain i.e., pain that lasts for 6–12 weeks;, and (c) chronic pain i.e., pain

that persists for more than 12 weeks (Wheeler, 1995). Most chronic back pain patients experience fear of pain, and hence tend to avoid physical activity, which results in tissue and structural changes. Ultimately, continuous back pain persists during their lifetime (Parkkola et al., 1993), and consequently, this causes secondary damage or recurrence of back pain (Deyo et al., 1990).

Surgical treatment, medication, physical therapy, and exercise have been proposed as treatments for low back pain. Pain causes jerky movements thus destabilizing the segmental spinal structure. This causes repetitive damage and degenerative changes in the muscles, discs, and posterior joints due to spinal flexion, extension, lateral flexion, rotation, and repetitive behaviors (Cailliet, 1998). Therefore, in the past conservative physical therapies such

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as hyperthermia, electrical, and traction therapies were applied but, exercises that involve the use of the lumbar muscles have been strongly recommended for a better solution. The effects of lumbar muscle exercise are various depending on exercise time, frequency, and types (Kofotolis and Sambanis, 2005). However, comparison studies of different types of exercise are limited, and effectiveness is hard to evaluate. The previous studies applied specific exercises with instruments such as slings, Medx, reformers or performed in swimming pools as aquatic exercises. These exercise methods aimed to enhance muscular strength and reduce low back pain, but these limit patients in terms of spontaneous and independent practice, without instructors, after the end of the study participation. In this regard, mat and gym ball for strength training, and step box were utilized for exercise programs in order to establish an independent exercise habit after this intervention study. Walking is known to be convenient, easy, and safe to access as a primary exercise to reduce low back pain as it does not include twisting or vigorous forward flexion (National Institute of Arthritis and Musculoskeletal and Skin Disease, 2014). Meta-analysis study (O'Connor et al., 2015) concluded that walking could be recommended as an effective form of exercise or activity. Additionally, walking was more effective than specific strength exercises or supervised exercise classes, and overground walking was superior to treadmill walking in adults with chronic low back pain (Lawford et al., 2016). In the meantime, the degree of obesity was found to be associated with low back pain (Bayramoğlu et al., 2001; Melissa et al., 2003).

Thus, the aim of this study was to verifying the effects of strength and combined (walking plus strength) exercise programs on lumbar function, pain level, and body composition in overweight adults with chronic lower back pain.

MATERIALS AND METHODS

Participants

The subjects of this study were recruited among overweight patients (body mass index > 23 kg/m^2) with chronic back pain at a Teun-Teun Hospital in Seoul through online and offline promotional materials. Inclusion in this study was limited to people who had not participated in regular exercise over the previous 6 months. In addition, subjects were selected if it was determined that they were able to exercise within a limited range of joint motion. In order to evaluate chronic lower back pain and neurological problems, a medical doctor diagnosed lower back pain patients with X-ray and magnetic resonance imaging results. Subjects were randomly placed in the strength exercise group (SEG, n = 15), combined exercise group (CEG, n = 15), and control group (CG, n = 6). All subjects signed participation agreements and their physical characteristics are shown in Table 1.

Exercise program

The strength exercise program for SEG comprises resistance training, which is performed on a mat or with a gymball. The combined exercise program for CEG comprise strength exercises plus walking exercises with a step box. All subjects from the exercise groups performed exercise twice per week, 50 min per session with a professional instructor, for 12 weeks. The instructor educated the subject to maintain moderate to somewhat hard intensity (rate of perceived exertion, 11–16) during the entire exercise session. The detailed programs for strength and combined exercises are shown in Tables 2, 3.

Table 1. Characteristics of subjects

Characteristic	SEG	CEG	CG
Age (yr)	42.7±13.4	46.7±8.1	43.3±9.9
Height (cm)	169.0±8.3	168.1±9.3	169.3±9.2
Weight (kg)	68.8±11.8	67.6±10.2	80.1±19.9
Body mass index (kg/m^2)	24.3±3.1	24.1±2.6	27.9±4.4

Values are presented as mean±standard.
SEG, strength exercise group; CEG, combined exercise group; CG, control group.

Table 2. Strength exercise program

Group	Order	Contents	Set	RPE
SEG	Warm-up (10 min)	Stretching	-	-
	Strength training (30 min)	Bridge Plank Squat Push-ups Back extension	3–5	11–16
	Cool-down (10 min)	Stretching	-	-

SEG, strength exercise group; RPE, rate of perceived exertion.

Table 3. Combined exercise program

Group	Order	Contents	Set	RPE
CEG	Warm-up (10 min)	Stretching step exercise	-	-
	Strength training (30 min)	Bridge Plank Step exercise Squat Push-ups Step exercise Back extension	3–5	11–16
	Cool-down (10 min)	Stretching step exercise	-	-

CEG, combined exercise group; RPE, rate of perceived exertion.

Measuring methods

Lumbar function

Back strength: Back strength measurement instruments (TKK 5402, Takei Scientific Instruments Co., Nigata, Japan) were used to evaluate back strength. In order to avoid injury all subjects performed a warm-up, and then the subject stood on a foot plate with both legs apart about 15 cm, and grasped the handle with straight knees and back. When the subjects were ready, they stretched the handle backwards using back muscles as much as they could. Tests were performed twice, and the higher score was recorded.

Flexibility: A sit and reach method was used to evaluate back flexibility. In order to avoid injury all subjects performed a warm-up. They sat on the ground on bended knees, without shoes with both arms stretched as much as they could without reactionary movement. When they did not move for longer than 2 sec, their score was recorded. They performed this twice and the better score was recorded.

Pain disorder degree

Disability from lower back pain: The Roland-Morris disability questionnaire (RMDQ) was used to evaluate the pain disorder degree. This aims to evaluate the disability degree due to lower back pain in daily life. This questionnaire is composed of 24 questions. Subjects were asked to choose 'Yes' or 'No' and a score of 1 is assigned to 'Yes'. A higher score denotes a worse degree of pain.

Visual pain scale by visual analogue scale: A visual analogue scale (VAS) was used to evaluate the degree of lower back pain. Numbers from 0 to 100 were recorded on the horizon, and a higher number denotes stronger pain. The subjects evaluated their degree of lower back pain subjectively and marked their numbers.

Body composition

Bio electrical impedance analysis (Inbody 370, Inbody, Seoul, Korea) was used to estimate the amount of fat and muscle. The subjects were asked not to move or speak during measurements.

Data analysis

The average and standard deviation of all variable data was calculated using IBM SPSS ver. 18.0 (IBM Co., Armonk, NY, USA). Two-way repeated measures analysis of covariance was performed to evaluate the effects of the 12 weeks period among the three groups. Age was used as a covariate to eliminate age effects on the results, and LSD was used as *post doc*. Statistical significance level was set at $P < 0.05$.

RESULTS

Lumbar function

The results of lumbar function (back strength and flexibility) after 12 weeks of exercises between the three groups are shown in Table 4. Back strength showed a significant different over time ($P < 0.040$), but group differences were not significant. In addition, time × group showed a significant difference ($P < 0.014$). *Post doc* analysis showed significant differences between SEG and CG, CEG and CG. These results indicate that 12 weeks of an exercise program can produce back strength improvement, but differences between exercise types could not be determined.

Flexibility did not show significant time and group differences. However, time × group difference was significant ($P < 0.038$). *Post hoc* analysis showed significant differences between SEG and CG, and CEG and CG. These results indicate that 12 weeks of an exercise program can improve flexibility but which exercise types are better could not be differentiated.

Pain disorder degree

Degree of pain disorder (RMDQ and VAS) after 12 weeks of exercises between the three groups are shown in Table 5.

VAS showed no significant time differences, but group differ-

Table 4. Changes of lumbar function

Variable	Group	Pre	Post		F	P-value	LSD
Back muscle strength (kg)	SEG	52.3 ± 25.3	81.8 ± 27.0	Time	4.607	0.040*	
	CEG	46.8 ± 18.2	78.0 ± 26.3	Group	1.157	0.328	
	CG	80.8 ± 31.6	84.3 ± 33.4	Time × group	4.973	0.014*	CG < SEG, CEG
Sit-and-reach (cm)	SEG	4.3 ± 10.3	10.2 ± 10.9	Time	3.307	0.079	
	CEG	2.0 ± 10.8	7.7 ± 8.3	Group	0.361	0.700	
	CG	6.7 ± 5.2	6.0 ± 4.8	Time × group	3.685	0.038*	CG < SEG, CEG

Values are presented as mean ± standard.
SEG, strength exercise group; CEG, combined exercise group; CG, control group; LSD, Fisher least significant difference.
*$P < 0.05$, statistically significant.

Table 5. Changes of pain disorder level

Variable	Group	Pre	Post		F	P-value	LSD
VAS	SEG	32.3±14.9	22.0±11.3	Time	0.417	0.524	
	CEG	45.3±14.8	33.1±20.0	Group	3.496	0.044*	
	CG	24.2±9.2	35.8±17.2	Time×group	4.471	0.020*	CG<SEG, CEG
RMDQ	SEG	3.8±3.7	1.1±0.9	Time	0.102	0.751	
	CEG	6.3±4.8	1.8±2.1	Group	2.668	0.086	
	CG	0.8±1.2	1.7±1.6	Time×group	3.463	0.045*	CG<CEG

Values are presented as mean±standard.
VAS, visual analogue scale; RMDQ, Roland-Morris disability questionnaire; SEG, strength exercise group; CEG, combined exercise group; CG, control group; LSD, Fisher least significant difference.
*$P<0.05$, statistically significant.

Table 6. Changes of body composition

Variable	Group	Pre	Post		F	P-value	LSD
Muscle (kg)	SEG	46.4±9.1	48.7±9.2	Time	0.313	0.580	
	CEG	46.6±10.3	48.0±10.3	Group	0.068	0.935	
	CG	50.8±13.3	51.8±13.2	Time×group	3.149	0.058	
Body fat (kg)	SEG	19.6±5.6	17.2±4.8	Time	0.067	0.797	
	CEG	18.2±6.7	17.0±6.6	Group	3.345	0.049*	
	CG	26.0±8.1	25.7±7.4	Time×group	3.464	0.045*	CG<SEG

Values are presented as mean±standard.
SEG, strength exercise group; CEG, combined exercise group; CG, control group; LSD, Fisher least significant difference.
*$P<0.05$, statistically significant.

ences were significant ($P<0.044$). Time×group difference on VAS was significant ($P<0.020$). *Post hoc* analysis showed significant differences between SEG and CG, and CEG and CG. These results indicate that performing 12 weeks of exercise programs are effective in reducing subjective pain scores; however, there was no difference between the exercise programs.

Time×group difference on RMDQ was significant ($P<0.045$). *Post hoc* analysis showed significant differences between CEG and CG. These results indicate that 12 weeks of combined exercise program can produce subjective pain relief.

Body composition

The changes in body composition (fat and muscle mass) after 12 weeks of exercises between the three groups are in shown Table 6. Muscle mass (kg) showed no time and group differences, nor was there a time×group difference. These results indicate that 2 types of exercise were not able to produce muscle mass difference.

Fat mass (kg) showed no significant time difference, but group difference was significant ($P<0.049$). In addition, time×group difference showed significant differences ($P<0.045$) between SEG and CG. These results indicate that strength exercise programs are able to produce a positive effect on fat mass reduction.

DISCUSSION

Lumbar function

Recurrence of chronic back pain is known to be due to imbalanced and weak muscles compared to people without pain. In addition, a lowered proprioceptive function leads to lower position sense, resulting in lumbar balance problems and lower back pain (O'Sullivan et al., 2003). In this regard, this study was designed to reduce lower back pain with two different exercise types. Both SEG and CEG showed significant improvement in lumbar function (back strength and flexibility), but the types of exercise did not result in significant differences. A previous meta-analysis reported that overground walking was superior to treadmill walking in improving disability status, function, and quality of life in adults with chronic back pain (Lawford et al., 2016). In our study, exercise programs were performed in an indoor classroom and a step box was utilized in the walking exercise. Our results support the evidence implying that combined walking exercise is superior to walking alone (Lawford et al., 2016). Also, our positive results with walking are related with the previous results that aerobic exercise may increase the blood flow and nutrients to the soft tissues in the back and improved the healing process and reducing stiff-

ness (Ullrich, 2016). Thus, our results suggest that indoor walking is also effective in the improvement of back pain related health problems. Various studies have shown that core exercise, muscle strength, lumbar stability, flexibility and low back pain are interrelated. Core strength is associated with lumbar instability (Willson et al., 2005) and lumbar instability reduces the flexibility of the lumbar spine (Cho et al., 2014). Also, the deep abdominal muscles including the superficial muscles, transversus abdominis muscle, and multifidus are important to reduce back pain (Amit et al., 2013). Stability exercise also has been shown to be effective in nonspecific chronic low back pain patients, and lumbar stabilization programs enhances the stability of the spine (Hicks et al., 2005).

However, muscular strength improvement was not always accompanied by relief of lumbar pain (Koumantakis et al., 2005; MacDonald et al., 2006). This indicates that exercises for strength and flexibility together with some other strategy are required for pain relief. In order to maximize strength and flexibility enhancement in this study the exercise programs were recomposed every 4 weeks. Each stage was programmed as core stability, strength, and power-balance training, and the instructor emphasized of the subject's proper exercise intensity and gradually improved it every 4 weeks. This strategy may be able to maximize muscle stimulation, contraction, and strength. Although a subjective intensity scale from the instructor was used, and this may contribute improved muscular strength. Importantly, the reprograming method may help to maintain a subject's motivation, which is a crucial factor in engagement with and completion of exercise intervention programs (Sevil et al., 2015; Viljoen and Christie, 2015).

Pain disorder degree

In lower back pain, muscles around the spine are contracted or have atrophied and this reduces the function of active supporting structures. Also, due to the repeated transfer of external forces, such as a pedestrian on their spine, ongoing stress accumulates. This deepens the instability of the spine and leads to chronic back pain (McConnell, 2002). In order to prevent recurrence of the back pain, flexibility of the waist and strengthening of the abdominal muscles has been suggested (Hwangbo et al., 2015). Acute pain relief also has been shown after manual and pharmacological therapies in chronic back pain patients. However, a long-term effect is more beneficial for patients, and this may be accompanied by muscle and ligament training. For this reason, exercise training such as Williams exercises, McKenzie exercises, extension exercises, aerobic and aquatic exercises and yoga have been developed and applied. These aimed to improve flexibility and muscle

strength, but they also apply excessive mechanical stress on the lumbar area. This causes little or relatively lower improvement in pain (Henchoz and Kai-Lik, 2008; Lee et al., 2015). Therefore, in our study various muscle-strengthening programs were designed and applied periodically so that different external stresses stimulate the lumbar muscle. In our study, both exercise groups showed a positive interaction effect of time by group by VAS and RMDQ tests. These results indicate that performing exercise has to be considered to relieve low back pain. Positive exercise effects have been shown with cycle ergometry exercise (Hoffman et al., 2005), individualized tailored aerobic exercise (Chan et al., 2011), running exercise (Chatzitheodorou et al., 2008), and stabilization exercise (Inani and Selkar, 2013; Šarabon et al., 2011).

In our study, walking exercise was included in CEG, and this group showed both VAS and RMDQ score improvements. In CEG, two sessions of step box walking for 5 min included between muscle exercises during the 30 min exercise programs. Because, continuous walking for 10 min produces loss of interest and motivation, and distraction of patients' concentration, we assumed the workout effects would be reduced. In addition, walking with a step box requires more muscle power in the lower extremities and spine area due to climbing and down motion movements compared with simple walking. This contributed to mobilization and developed muscle strength resulting in reduced pain levels. Also, walking exercise was performed as an aerobic exercise and it increases the production of endorphins, which bind to the opiate receptors in the pain control system in the brain and spinal cord to decrease the perception of pain (Kenny et al., 2012).

Our results emphasize not only performing exercise, but also that exercise program configuration to maximize muscle strength and power, and mode of walking exercise are important factors in reducing low back pain.

Body composition

Chronic low back pain is caused by anatomical configuration changes in the muscles around the spine. Additionally, it is induced by a decrease in the muscle cross sectional area, and fat accumulation in the muscle (Silfies et al., 2005). Therefore, in order to improve muscle contraction ability and prevent atrophy, muscle training on trunk and abdominal muscles, extension and external muscles of the hip are recommended (Adams et al., 2002).

The association between body composition, low back pain, and disability has been examined that low back pain was shown to be associated with significant improvement of body composition such as weight, body mass index, body fat percentage, and skele-

tal muscle mass (Baena-Beato et al., 2014). These results imply that positive changes to manage one's body composition components may reduce the risk of back pain. In our study, muscle mass did not show significant interaction effect of time by group. Exercise intensity, time, sequence, and types in our study were designed for overweight back pain patients and these probably were not enough to produce significant improvements after 12 weeks. However, body fat mass showed significant differences by group, and interaction effect of time by group. These results imply that walking with a strength exercise program may be suitable for prevention of lower back pain. Recent meta-analysis (Shiri et al., 2010), cross-sectional and prospective studies (Heuch et al., 2013; Nilsen et al., 2011) support the above relationships. A cohort study (Heuch et al., 2015) also reported that increased body weight was associated with back pain. This report suggests that proper body weight management with exercise is recommended for lower back pain prevention.

A heavy mechanical load, i.e., body weight, may apply greater compressive forces on the structures of the lumbar spine (Shiri et al., 2010), and this can be a possible mechanism for the relationship between body composition components and low back pain. Structural modifications involving disc degeneration (Liuke et al., 2005) is associated with increasing load. In addition, limited spinal mobility in overweight individuals affects blood supply to the lumbar region, and adiposity (Kauppila et al., 1997). Fat tissue is generally known to be associated with elevated cytokines (Tilg and Moschen, 2006), and activated pro-inflammation. This mechanism is a final cause of low back pain. In the meantime, although the data and results are not provided in this paper, a researcher conducted personal interviews after completion of the exercise sessions. We found and concluded that emotional and psychological factors with participation of exercise programs also contribute to relief of back pain.

In summary, performing exercise rather than exercise type is a major contributing factor to improving lumbar function. Combined exercise programs, e.g., walking with a step box and strength exercises, are more effective for reducing pain levels than strength exercise alone. Lastly, fat mass was reduced in this study and this may play a possible role in the improvement of lumbar function and reduction in low back pain.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

REFERENCES

Adams MA, Bogduk N, Burton K, Dolan P. The biomechanics of back pain. Edinburgh: Churchill Livingstone; 2002.

Amit K, Manish G, Taruna K. Effect of trunk muscles stabilization exercises and general exercises on pain in recurrent non specific low back ache. Int Res J Med Sci 2013;1:23-26.

Baena-Beato PÁ, Artero EG, Arroyo-Morales M, Robles-Fuentes A, Gatto-Cardia MC, Delgado-Fernández M. Aquatic therapy improves pain, disability, quality of life, body composition and fitness in sedentary adults with chronic low back pain. A controlled clinical trial. Clin Rehabil 2014;28:350-360.

Bayramoğlu M, Akman MN, Kilinç S, Cetin N, Yavuz N, Ozker R. Isokinetic measurement of trunk muscle strength in women with chronic low-back pain. Am J Phys Med Rehabil 2001;80:650-655.

Cailliet R. Low back pain. 4th ed. Philadelphia: FA Davis; 1998.

Chan CW, Mok NW, Yeung EW. Aerobic exercise training in addition to conventional physiotherapy for chronic low back pain: a randomized controlled trial. Arch Phys Med Rehabil 2011;92:1681-1685.

Chatzitheodorou D, Mavromoustakos S, Milioti S. The effect of exercise on adrenocortical responsiveness of patients with chronic low back pain, controlled for psychological strain. Clin Rehabil 2008;22:319-328.

Cho HY, Kim EH, Kim J. Effects of the CORE exercise program on pain and active range of motion in patients with chronic low back pain. J Phys Ther Sci 2014;26:1237-1240.

Deyo RA, Walsh NE, Schoenfeld LS, Ramamurthy S. Can trials of physical treatments be blinded? The example of transcutaneous electrical nerve stimulation for chronic pain. Am J Phys Med Rehabil 1990;69:6-10.

Hanney WJ, Masaracchio M, Liu X, Kolber MJ. The influence of physical therapy guideline adherence on healthcare utilization and costs among patients with low back pain: a systematic review of the literature. PLoS One 2016;11:e0156799.

Henchoz Y, Kai-Lik So A. Exercise and nonspecific low back pain: a literature review. Joint Bone Spine 2008;75:533-539.

Heuch I, Heuch I, Hagen K, Zwart JA. A comparison of anthropometric measures for assessing the association between body size and risk of chronic low back pain: The HUNT Study. PLoS One 2015;10:e0141268.

Heuch I, Heuch I, Hagen K, Zwart JA. Body mass index as a risk factor for developing chronic low back pain: a follow-up in the Nord-Trøndelag Health Study. Spine (Phila Pa 1976) 2013;38:133-139.

Hicks GE, Fritz JM, Delitto A, McGill SM. Preliminary development of a clinical prediction rule for determining which patients with low back pain will respond to a stabilization exercise program. Arch Phys Med Rehabil 2005;86:1753-1762.

Hoffman MD, Shepanski MA, Mackenzie SP, Clifford PS. Experimentally induced pain perception is acutely reduced by aerobic exercise in people with chronic low back pain. J Rehabil Res Dev 2005;42:183-190.

Hoy D, Bain C, Williams G, March L, Brooks P, Blyth F, Woolf A, Vos T, Buchbinder R. A systematic review of the global prevalence of low back pain. Arthritis Rheum 2012;64:2028-2037.

Hwangbo G, Lee CW, Kim SG, Kim HS. The effects of trunk stability exercise and a combined exercise program on pain, flexibility, and static balance in chronic low back pain patients. J Phys Ther Sci 2015;27:1153-1155.

Inani SB, Selkar SP. Effect of core stabilization exercises versus conventional exercises on pain and functional status in patients with non-specific low back pain: a randomized clinical trial. J Back Musculoskelet Rehabil 2013;26:37-43.

Kauppila LI, McAlindon T, Evans S, Wilson PW, Kiel D, Felson DT. Disc degeneration/back pain and calcification of the abdominal aorta. A 25-year follow-up study in Framingham. Spine (Phila Pa 1976) 1997;22:1642-1647.

Kenny WL, Wilmore JH, Costill DL. Physiology of sport and exercise. 5th ed. Champaign (IL): Human Kinetics; 2012.

Kofotolis N, Sambanis M. The influence of exercise on musculoskeletal disorders of the lumbar spine. J Sports Med Phys Fitness 2005;45:84-92.

Koumantakis GA, Watson PJ, Oldham JA. Trunk muscle stabilization training plus general exercise versus general exercise only: randomized controlled trial of patients with recurrent low back pain. Phys Ther 2005;85:209-225.

Lawford BJ, Walters J, Ferrar K. Does walking improve disability status, function, or quality of life in adults with chronic low back pain? A systematic review. Clin Rehabil 2016;30:523-536.

Lee M, Song C, Jo Y, Ha D, Han D. The effects of core muscle release technique on lumbar spine deformation and low back pain. J Phys Ther Sci 2015;27:1519-1522.

Liuke M, Solovieva S, Lamminen A, Luoma K, Leino-Arjas P, Luukkonen R, Riihimäki H. Disc degeneration of the lumbar spine in relation to overweight. Int J Obes (Lond) 2005;29:903-908.

MacDonald DA, Moseley GL, Hodges PW. The lumbar multifidus: does the evidence support clinical beliefs? Man Ther 2006;11:254-263.

McConnell J. Recalcitrant chronic low back and leg pain: a new theory and different approach to management. Man Ther 2002;7:183-192.

Melissas J, Volakakis E, Hadjipavlou A. Low-back pain in morbidly obese patients and the effect of weight loss following surgery. Obes Surg 2003;13:389-393.

National Institute of Arthritis and Musculoskeletal and Skin Diseases. Handout on Health: Back pain [Internet]. Bethesda (MD): National Institute of Health; 2014 [cited 2016 Feb 25]. Available from: http://www.niams.nih.gov/Health_Info/Back_pain/.

Nilsen TI, Holtermann A, Mork PJ. Physical exercise, body mass index, and risk of chronic pain in the low back and neck/shoulders: longitudinal data from the Nord-Trondelag Health Study. Am J Epidemiol 2011;174:267-273.

O'Connor SR, Tully MA, Ryan B, Bleakley CM, Baxter GD, Bradley JM, McDonough SM. Walking exercise for chronic musculoskeletal pain: systematic review and meta-analysis. Arch Phys Med Rehabil 2015;96:724-734.e3.

O'Sullivan PB, Burnett A, Floyd AN, Gadsdon K, Logiudice J, Miller D, Quirke H. Lumbar repositioning deficit in a specific low back pain population. Spine (Phila Pa 1976) 2003;28:1074-1079.

Parkkola R, Rytökoski U, Kormano M. Magnetic resonance imaging of the discs and trunk muscles in patients with chronic low back pain and healthy control subjects. Spine (Phila Pa 1976) 1993;18:830-836.

Šarabon N, Palma P, Vengust R, Strojnik V. Effects of trunk functional stability training in subjects suffering from chronic low back pain: a pilot study. Kinesiol Slov 2011;17:25-37.

Sevil J, Práxedes A, Abarca-Sos A, Del Villar F, García-González L. Levels of physical activity, motivation and barriers to participation in university students. J Sports Med Phys Fitness 2015 Nov 10 [Epub].

Shiri R, Karppinen J, Leino-Arjas P, Solovieva S, Viikari-Juntura E. The association between obesity and low back pain: a meta-analysis. Am J Epidemiol 2010;171:135-154.

Silfies SP, Squillante D, Maurer P, Westcott S, Karduna AR. Trunk muscle recruitment patterns in specific chronic low back pain populations. Clin Biomech (Bristol, Avon) 2005;20:465-473.

Smith M, Davis MA, Stano M, Whedon JM. Aging baby boomers and the rising cost of chronic back pain: secular trend analysis of longitudinal Medical Expenditures Panel Survey data for years 2000 to 2007. J Manipulative Physiol Ther 2013;36:2-11.

Tilg H, Moschen AR. Adipocytokines: mediators linking adipose tissue, inflammation and immunity. Nat Rev Immunol 2006;6:772-783.

Ullrich PF. Low impact aerobic exercise [Internet]. Deerfield (IL): Spine-health.com; c1999-2016 [cited 2016 Feb 25]. Available from: http://www.spine-health.com/wellness/exercise/low-impact-aerobic-exercise.

Viljoen JE, Christie CJ. The change in motivating factors influencing commencement, adherence and retention to a supervised resistance training programme in previously sedentary post-menopausal women: a prospective cohort study. BMC Public Health 2015;15:236.

Wheeler AH. Diagnosis and management of low back pain and sciatica. Am Fam Physician 1995;52:1333-1341, 1347-1348.

Willson JD, Dougherty CP, Ireland ML, Davis IM. Core stability and its relationship to lower extremity function and injury. J Am Acad Orthop Surg 2005;13:316-325.