ISSN 0008-3194 (p)/ISSN 1715-6181 (e)/2021/193–206/$2.00/©JCCA 2021

Neuromuscular exercises on pain intensity, functional disability, proprioception, and balance of military personnel with chronic low back pain

Ehsan Alvani, MSc[1]
Hossein Shirvani, PhD[1]
Alireza Shamsoddini, PhD[1]

Background: *Due to their occupational status, military personnel are a high-risk group for low back pain (LBP).*

Purpose: *The aim of this study was to investigate the effect of neuromuscular exercises on the severity of pain, functional disability, proprioception, and balance in military personnel with LBP.*

Methods: *Military personnel with LBP were randomly assigned into two groups: intervention (n=15) and control (n=15). The intervention group performed 60 minutes of neuromuscular exercises three times per week for eight weeks while the control group continued their routine physical activities.*

Results: *The mean post-intervention pain intensity, disability, and proprioception error significantly*

Des exercices neuromusculaires pour réduire l'intensité de la douleur, diminuer l'incapacité fonctionnelle et améliorer la proprioception et l'équilibre chez les militaires aux prises avec la lombalgie chronique

Contexte : *En raison de leur profession, les militaires sont très exposés à la lombalgie.*

Objectif : *Cette étude consistait à examiner l'effet des exercices neuromusculaires sur l'intensité de la douleur, l'incapacité fonctionnelle, la proprioception et l'équilibre chez les militaires aux prises avec la lombalgie.*

Méthodes : *Des militaires souffrant de lombalgie ont été répartis au hasard en deux groupes : le groupe sous traitement (n=15) et le groupe témoin (n=15). Les sujets du groupe sous traitement ont fait 60 minutes d'exercices neuromusculaires trois fois par semaine pendant huit semaines, alors que le groupe témoin a poursuivi ses activités physiques de manière habituelle.*

Résultat : *L'intensité moyenne de la douleur, l'invalidité et le déficit proprioceptif ont significativement diminué*

[1] Department of Exercise Physiology Research Center, Baqiyatallah University of Medical Sciences, Tehran, Iran

Corresponding author: Alireza Shamsoddini, Exercise Physiology Research Center, Life Style Institute, Baqiyatallah University of Medical Sciences, Tehran, Iran
Tel: + 9821 87554402
Fax: +9821 88600030
E-mail: alirezaot@bmsu.ac.ir

The authors have no disclaimers, competing interests, or sources of support or funding to report in the preparation of this manuscript. This study was approved by the Ethics Committee of Baqiyatallah University of Medical Sciences, Tehran (IR.BMSU.AC.IR.REC. 01398.014). In addition, this project in the Iranian clinical trial system with number (IRCT20190427043384N1) is registered.

decreased in the intervention group. Whereas their mean post-interventions static and dynamic balance scores significantly increased.

Conclusions: *The results indicate eight weeks of neuromuscular exercise decreased pain intensity and improved functional ability, static and dynamic balance, and proprioception among military staff suffering chronic low back pain.*

(JCCA. 2021;65(2):193-206)

KEY WORDS: chronic low back pain, military personnel, proprioception, pain intensity, functional disability, balance

dans le groupe sous traitement, alors que les cotes moyennes attribuées à l'équilibre statique et dynamique post-intervention ont augmenté de façon appréciable.

Conclusions : *Les résultats montrent que les exercices neuromusculaires pratiqués pendant huit semaines ont permis de réduire l'intensité de la douleur et d'améliorer la capacité fonctionnelle, l'équilibre statique et dynamique et la proprioception chez des militaires aux prises avec la lombalgie chronique.*

(JCCA. 2021;65(2): 193-206)

MOTS CLÉS : lombalgie chronique, personnel militaire, proprioception, intensité de la douleur, incapacité fonctionnelle, équilibre

Introduction

Low back pain (LBP) is one of the most common and costly musculoskeletal problems in modern society[1], which affects almost everyone at least once over their lifetime[2]. Considering that the cause of low back pain is multifactorial, investigating physical, psychological and social factors is essential for better management of this condition.[3] LBP occurs in all age groups from children to the elderly[4,5], and it is the leading cause of disability and work absenteeism worldwide[6]. This has led to substantial expenses for the general public as a whole.[7]

Chronic LBP is associated with histomorphologic and structural changes in the paraspinal muscles.[8] In addition, chronic LBP is linked to subsequent musculoskeletal system deficiencies, such as decreased range of motion, changes in lumbar proprioception and muscle density.[9] Chronic LBP may have different etiologies with several neuromuscular factors including muscular imbalance, poor postural control, the decreased proprioception accuracy, and sacroiliac joint dysfunction.[10]

LBP is furthermore a common and high-risk problem among the military personnel due to their active work environment. Musculoskeletal injuries are the main cause of disability among military personnel.[11] Notably, around 20% of musculoskeletal disorder diagnoses resulting in disability among military personnel are back related.[12]

Most LBP patients develop chronic pain and disability, both of which can cause personal and economic burdens.[13] Meanwhile, pain is known to be one of the first manifestations of LBP pathology and can lead to restricted activity in patients. In this regard, there is a disagreement on explaining the mechanism of how pain causes disability. Findings suggest there is a close association between pain perception and disability.[14] Yang *et al*.[15] suggest pain in chronic LBP patients causes impaired movement control, and fear of pain recurrence at different times causes increased disability as well as restricted activity. In a different study, patients had decreased movement control and performance when changing postures, and they experienced diminished movement control and functions in other dimensions of their lives.[16] Moreover, movement control is an essential need for the body to perform and function normally.[17]

Smidt *et al*.[18] report treatments that enhance flexibility and increase abdominal and extensor back muscle power are beneficial for both acute and chronic LBP. They furthermore found performing kinesiotherapy with the above-mentioned goals is often incorporated into programs for the patients with LBP. "Kinesiotherapy comprises of different types of therapeutic exercises such as stretching and strengthening (isotonic, isokinetic, and isometric)."[19] Neuromuscular exercises are also important in improving the coordination, power, range of motion, and proprioception in these patients with chronic LBP. These exercises affect sensory receptors of the joints, which send information related to the body's position during movement.[20] In this regard, neuromuscular exercises can improve back muscle control, flexibility, and power.[21] The general aim of neuromuscular exercises is reversing the disorders resulting from pain as well as enhancing the muscular strength and endurance required in activities.[22] We hypothesized that a neuromuscular exercise intervention would reduce pain intensity and disability in military personnel as compared to those receiving only general exercise. Therefore, the main aim of this study was to investigate the effect of neuromuscular exercises on the severity of pain, functional disability, proprioception, and balance of military staff with chronic LBP.

Methods

The present study was a randomized controlled trial with a pre- and post-test design consisting of intervention and control groups. Prior to initiating the research and any intervention, the Baqiyatallah University of Medical Sciences ethics committee approved the study (IR.BMSU.AC.IR.REC. 01398.0142). This study was also registered (IRCT20190427043384N1) with the Iranian Registry of Clinical Trials (IRCT).

In the current study, we investigated the effect of neuromuscular exercises on pain intensity, functional disability, proprioception, and balance of military personnel with chronic non-specific LBP. Non-specific low back pain is defined as low back pain not attributable to a recognizable, known specific pathology (e.g., infection, tumor, osteoporosis, lumbar spine fracture, structural deformity, inflammatory disorder, radicular syndrome, or cauda equina syndrome).[23]

The study population consisted of military men aged 20- to 50-years old suffering from chronic non-specific LBP who were referred to hospital clinics in Tehran, Iran. Patients were randomly assigned into one of two treatment groups at a 1:1 ratio as follows: intervention group (n = 15) or control group (n = 15). The randomization was performed by an individual who was not involved in other procedural aspects of the study. Randomization was achieved by drawing a number from 1 to 30 prepared in advance and placed in sealed opaque envelopes in a box. All outcomes were assessed pre- and post-intervention by a blinded assessor. Due to their military experience, subjects were sufficiently trained and experienced to perform the objective tests. Other inclusion criteria for this study were: 1) a history of LBP for more than three months; 2) evidence of chronic LBP confirmed by a physical medicine and rehabilitation specialist; 3) the absence of any specific pathology in the vertebral column such as disc herniation, fracture, vertebral column surgery, or infection; 4) a score at least three on the visual analog scale (VAS) pain test; 5) the abilities to sit, stand, and walk without auxiliary devices and to perform normal daily activities. The exclusion criteria were no consent by the subject, damage to the lumbar region during the treatment period, a diagnosis of any systemic arthropathy, asthma, cancer, diabetes, and/or having a psychological disease.

As shown in Figure 1, 45 individuals were identified as meeting the inclusion criteria. Out of these subjects, 30 patients were randomly assigned into two groups: a group that underwent a neuromuscular exercise intervention (n=15) and a control group (n=15). Sample size

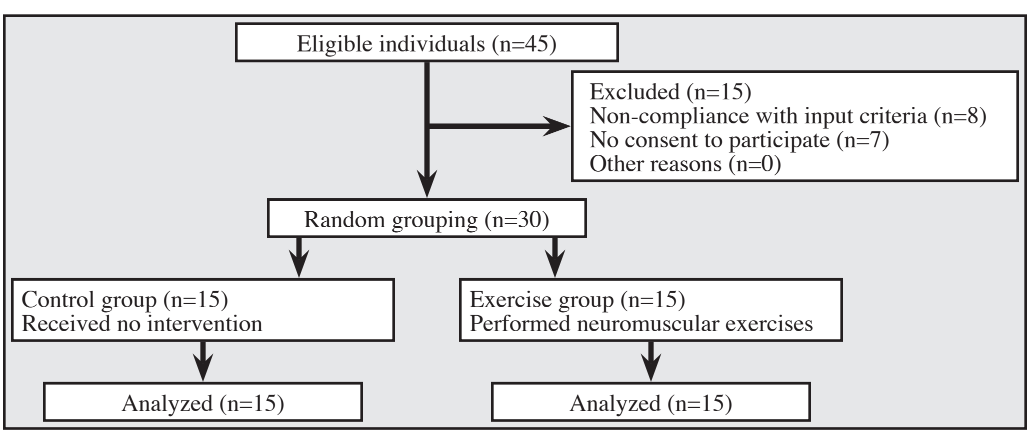


Figure 1. *Research process flowchart*

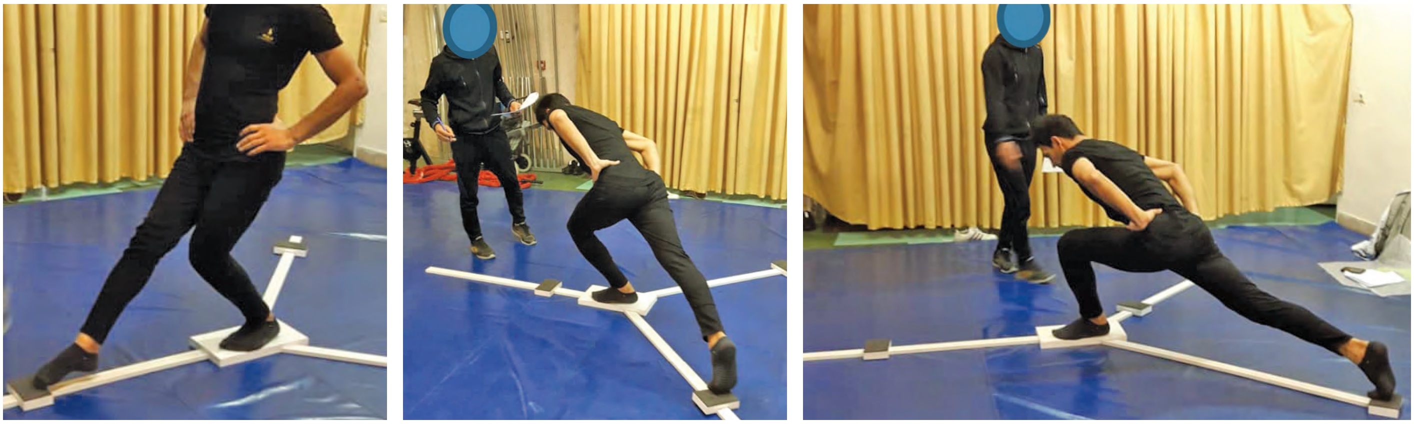


Figure 2.
The Y balance test (YBT) across different directions

calculations using G-Power software as in previous studies[24,25] resulted in 30 patients (15 patients per group). Considering the 20% attrition rate, an effect size of 0.25, a statistical power of 95%, and an alpha of 0.05 (two-tailed test), a total sample size of 30 was required (15 patients per group). A written informed consent form was received from all the subjects. After all subjects were informed of their right to leave the study at any time, their anthropometric characteristics, including their height, weight, age, and duration of LBP, were recorded. After completing the quality of life questionnaire, the severity of pain test (VAS), the Oswestry (functional disability) questionnaire, proprioception test, as well as static (stork balance) and dynamic balance (Y balance) tests [YBT]) were conducted. All evaluations were performed by testers who were blind to participant group allocation. This study was completed within eight weeks, and no intervention nor outcome measure was continued after its completion.

During the research period, both groups performed their daily routine physical and exercise activities. The intervention group also performed the neuromuscular exercises according to the research protocol for three sessions per week for eight weeks with each session lasting for 60 minutes. During the intervention, the control group performed their routine sports and physical activities and did not receive any additional training. At the end of the intervention, all variables of the research were measured again and recorded.

Visual analog scale (VAS) for pain measurement

The VAS, a widely used psychometric response scale tool, was employed to measure subjects' pain severity. Subjects were asked to indicate the severity of their pain along the VAS, which is a horizontal line with 11 points along it. The beginning shows no pain (marked with a zero and an image of a smiling face), and its endpoint (marked with a 10 and a face in pain and discomfort) represents very severe pain. Its reliability and validity have been excellent, and its internal consistency has been shown as ICC=0.91.[26] The validity of the VAS scale is based on Cronbach alpha that has been reported to be 0.95.[27]

Functional disability

In the present study, the Oswestry questionnaire was used to assess the degree of disability in subjects with chronic LBP. This questionnaire includes 10 six-option items. These 10 items examine the performance of the individuals in their daily activities. Each item ranks the degree of disability in performance from zero (desired function with no feeling of pain) up to five (disability in performing the activity due to severe pain).

The Oswestry disability index is equal to sum of the scores of these 10 items multiplied by 2, the value of which ranges from 0 to 100. A score of zero indicates the person is able to perform daily activities with no pain. A 0-20 score indicates mild or minimal disability, 21-40 indicates moderate disability, 41-60 indicates severe disability, and 61-80 indicates crippling disability. Scores 81 and higher indicate the person is bed-bound or exaggerating symptoms.[28] The validity of Oswestry questionnaire has been confirmed based on Cronbach alpha of 75%, and its reliability has been reported with a correlation coefficient of 0.92 using the test-retest method.[29]

Dynamic balance assessment

The YBT was used to assess dynamic balance. Previous studies have proven YBT is reliable and valid as a dynamic test for balance.[30,31] The YBT device used for this study (Qamat Pouyan Company, Iran) measured anterior, anteroposterior, and posterior directions of movement (Figure 2).

The current study's subjects were instructed to stand on their support foot on the YBT device's center box. Each participant was instructed to maintain balance on their supporting (right) leg while performing the test using their non-supporting (left) leg. To perform the test, subjects pushed the indicator box forward as far as possible along the anterior, anteroposterior, and posterior planes with their left feet. Afterward, they repeated the same procedure with their left leg as the support leg. The test was repeated three times in each direction with both feet. Subsequently, after three times of repeating the test in each direction, a short rest (10-15 seconds) was given to the subjects to prevent fatigue.[32] In order to minimize the learning effects, each subject practiced this test in all the three directions six times with 15 seconds rest intervals.

After five minutes of rest, the final assessment was performed. Results were discarded and the subject asked to repeat the test if their support leg moved or they lost balance and placed their nonsupport foot on the ground. The length of leg was measured from anterior superior iliac spine (ASIS) up to the medial malleolus. To obtain the total balance score of the three directions average (i.e., anterior, anteroposterior, and posterior), the following formula was used:

$$CS = A+PL+PM/\ 3x \text{ leg length } x100$$

where *CS* = composite score, *A* = anterior, *PL* = posterolateral, and *PM* = posteromedial.

Stork balance test

The stork balance test was used to assess subjects' static balance.[33] Subjects were asked to stand on one (support) leg without shoes while lifting the foot of the opposite (nonsupport) leg toward the inner part of the support leg's knee and then to place the hands on the hips (Figure 3).

Figure 3.
The stork balance test

Subjects were instructed to keep their eyes open and focus on the wall directly in front of them. They then stood on the ball of their foot of the support leg and tried to preserve their balance. The test would conclude when an error in balance (e.g., the heel touched the ground, the foot on the ground moved, the hands were moved off of the hips, or the foot of bent leg was moved off of the support leg) was observed. When starting the measurement using a chronometer (Professional model, Iran), the time of standing on one leg until the loss of this status was recorded up to the closest hundredth of a second. Each subject performed the stork balance test three times, and their best performance was recorded.[34] The test-retest reliability coefficient of this test is reported to be 0.87.[35]

Proprioception measurement method

In this study, proprioception was measured by a goniometer (MSD, Belgium) with international standard of measurement (STFR). In this regard, the procedure of the pelvic lumbar proprioception measurement was introduced by Newcomer et al. with reliability and validity of 91% and 87%, respectively.[36]

In our study, to reduce proprioception feedback from the lower limb and pelvis, prevent the pelvis from receding during bending, and separate the trunk and pelvic movements, the lower limbs were immobilized in the areas of the shin, knee, and hip with a special frame provided by the researcher. Subsequently, markers were attached to the external upper surface of the arm, iliac crest, and the greater trochanter of femur. Next, subjects were positioned in a

Figure 4.
The proprioception test

relaxed standing posture without wearing shoes or socks. The legs were open to the width of the shoulders. Subjects then crossed their arms and placed their hands in front of their shoulders, so they would not use the contact between their palms and anterior surface of the hips during bending as a guide to achieve the target angle. In this regard, the position of a subject's neck was maintained in its normal position. Researchers instructed the subjects to close their eyes to eliminate visual afferents.

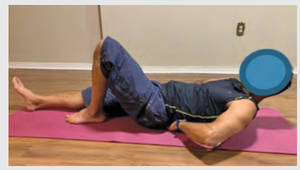
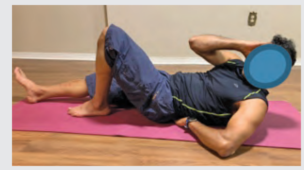
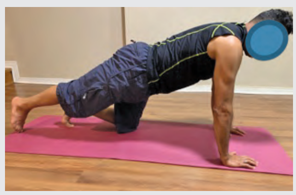
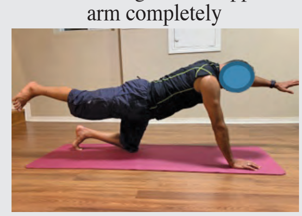
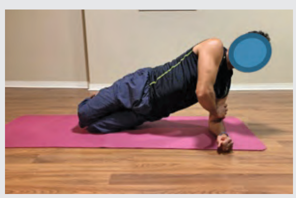
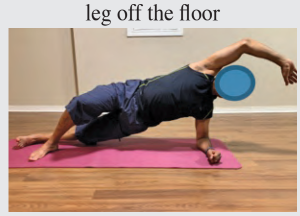
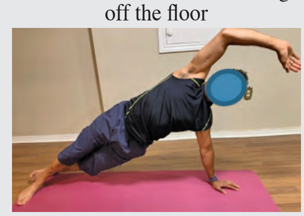
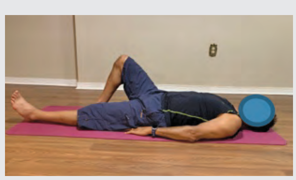
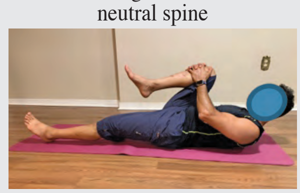
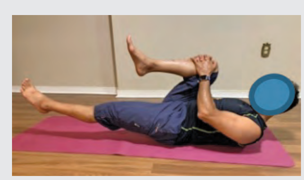
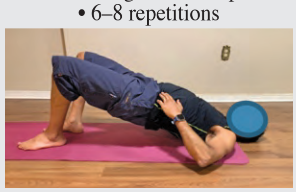
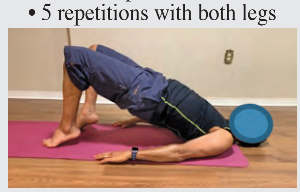
Next, the center of the goniometer was placed on the iliac crest, where one of the arms of the goniometer was aligned to the greater trochanter, while the other arm was adjusted to a 30° angle. The subjects were asked to bend with uniform speed and relatively slowly up to a 30° angle with closed eyes (Figure 4). They were then asked to remember this position with a five-second pause (at this stage, termination of the movement was notified to the subjects using an auditory stimulus). Then, subjects were instructed to return slowly to their initial standing position, and they began the next movement after a five second pause. After three repetitions (for learning), at the test stage, subjects should have reproduced the 30° angle in the bent position with no auditory stimulus. The test was repeated three times, and subjects' errors were recorded based on degree. The error value in each movement was the deviation between the above-mentioned angles from the target angle. In addition, the mean error value in the regeneration of posture in the three replications was recorded as the posture regeneration error.[37]

Exercise protocol

In this study, a neuromuscular exercise intervention was created for military personnel with chronic LBP. Each exercise session was performed in three stages as follows:

1. Warm up for 10 min with stretching exercises and light walking in the gym area.
2. Perform specific exercises that enhance the stability of vertebral column, improve the stamina of the abdominal muscles, improve balance and control posture, increase back muscle strength, and increase the lumbar and pelvic range of motion in terms of the protocol of the study for 45 min (Table 1).
3. Stretch and perform other cooling down movements for 5 min.

Table 1. *Neuromuscular exercise protocol*

	Exercise Type	Level 1	Level 2	Level 3
Week 1	McGill curl up (modified curl up): subjects lay supine with one knee in flexion and the other leg completely straight with the hands under the lumbar lordosis. Curl-ups were performed without pressing the lumbar spine down. • 6–8 repetitions on each side	Curl the torso upward with elbows on the floor 	Curl the torso upward with elbows off the floor 	Curl the torso upward and point one elbow towards the opposite knee while keeping the hip joint flexed 
Week 2	Bird dog stretch: subjects performed four-point kneeling by pressing the hands and shins towards the floor to stabilize the shoulder region and neutralize the lumbar vertebrae. The stretch was performed by extending one hand straightforward and the opposite leg straight backward; the test was repeated on each side. • 6–8 repetitions on each side	Stretch one leg out on the floor 	Lift the leg to the same level as the trunk 	Stretch one leg and the opposite arm completely 
Week 3	Side bridge or mermaid side bridge with bent knees: subjects laid on one side with their legs straight and then pressed their forearm onto the floor to lift their bodies so that only the forearm and foot touched the floor (side bridge), or they laid on one side with their legs bent at the knee and pressed their forearm onto the floor to lift their bodies so that only the forearm and knee and lower leg touched the floor (mermaid side bridge with bent knees). • 6–8 repetitions on each side	Lift the pelvis up 	Extend the arm and lift the lower leg off the floor 	Extend the arm and lift both legs off the floor 
Week 4	Single leg stretching • 8–10 repetitions on each side	From a supine crook lying position, stretch one leg on the floor and then draw it back while maintaining a neutral spine 	From a supine crook lying position, pull the head and shoulders off the mat and draw one leg to the chest while stretching the other leg straight on the floor; switch the legs and maintain a neutral spine 	From a supine crook lying position, stretch one leg on the floor and then draw it back while maintaining neutral spine 
Week 5	Shoulder bridge	From a supine crook lying position, lift the pelvis up while maintaining a neutral spine • 6–8 repetitions 	Perform a Level 1 shoulder bridge, then lift one heel from the floor with no pelvis rotation • 5 repetitions with both legs 	From a supine crook lying position, lift up the pelvis and maintain a neutral spine • 6–8 repetitions with both legs 

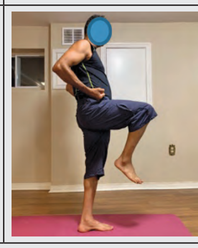
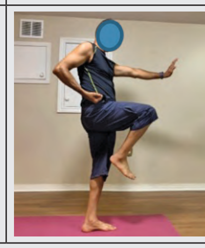
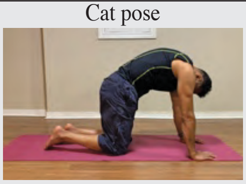
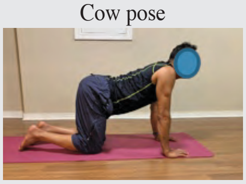
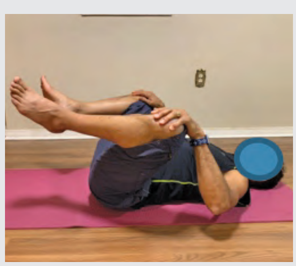
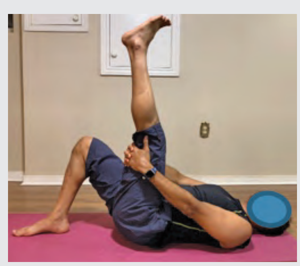
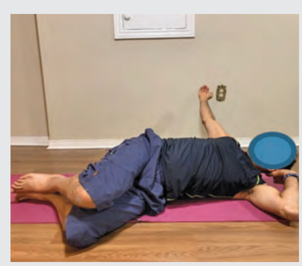
	Exercise Type	Level 1	Level 2	Level 3
Week 6	"Tai chi Warrior" stance	1) Lean forward on the left leg while bending the left knee to 90° while straightening the right leg to the rear and keeping the hands on the hips; 2) stand straight on the left leg while raising the right foot and bending the right knee 90°; 3) repeat on the other side	1) Lean forward on the left leg while bending the left knee to 90° while straightening the right leg to the rear and the right arm to the front and resting the left hand on the hip; 2) stand on the left leg while raising the right foot and bending the right knee to 90° and bring the right hand to the right hip; 3) repeat on the other side	Lean forward on the left leg while bending the left knee to 90° while straightening the right leg to the rear and the right arm to the front (the left hand rests on the hip); 2) stand on the left leg while raising the right foot and bending the right knee to 90° and bring the right hand to the right hip and straighten the left arm to the front; 3) repeat on the other side
		1 	1 	1 
		2 	2 	2 
Weeks 7 & 8	"Cat – cow – downward facing dog" yoga poses • Intended to achieve a normal range of motion in the thoracic region and in the hips and ankles) • 6 repetitions	Hip circumduction • Intended to emphasize flexion and abduction with the help of the hands while maintaining a neutral spine • After 5 repetitions, change the direction and repeat	Hamstrings stretch • Flex and point the ankle 8 times while maintaining a neutral spine • Change legs and repeat	Starting position • 1) Lay on the side with hips and knees flexed; 2) extend the upper arm upwards while maintaining a neutral spine; 3) rotate the thoracic spine backwards without moving the pelvis. • 6 repetitions
	Cat pose  Cow pose  Downward facing dog pose 			

Table 2.
Subject characteristics

Group	Mean±SD of BMI (kg)	Mean±SD of weight (kg)	Mean±SD of height (cm)	Mean±SD of age (years old)	Number
Control	25.48±3.90	78.60±10.99	175.87±5.78	30.67±7.84	15
Experimental	28.12±4.04	87.73±13.61	176.60±6.57	40.60±6.03	15
BMI: body mass index, kg: kilogram, cm: centimeter					

To achieve the normal range of motion in each exercise, the subjects received instruction on how to contract the trunk muscles to maintain a neutral vertebral column posture.[38,39,40,41]

Statistical analysis

Data normality was confirmed by the Shapiro-Wilk test. In addition, descriptive statistics were used to calculate the central tendency and distribution indices. Levene's test was also used to determine the homogeneity of variance in each group. A Two-way ANOVA test was used for inferential analysis of the obtained data. A Two-way ANOVA test was used to determine the post-intervention outcome measure scores in the intervention and control groups. Each dependent variable was analyzed with Two-way ANOVA test with group (intervention/control) as the between-subjects factor, and time (pre/post) as the within-subjects factor. All statistical analyzes were performed using SPSS (version 25).

Results

The mean and standard deviation of the personal characteristics of the control and intervention subjects, which included their age, height, weight, and BMI, are shown in Table 2. In the pre-test, the groups had no significant difference with each other in any of the demographic variables ($p>0.05$) (Table 2).

There were no statistically significant main effects for group or time for any of the dependent variables (all $p > .05$). However, there were significant interaction effects for pain intensity ($p < .001$), level of disability ($p = .044$), static balance ($p = .017$), dynamic balance ($p = .015$), and proprioception ($p = .021$).

Minimal clinically significant difference (MCID) pain scores[42] intensity and level of disability scores (Oswestry) were set at 2 and 6 respectively. The mean post-intervention pain intensity and level of disability scores significantly decreased in the intervention group compared to control by 2.1 and 7 points, respectively. On the other hand, the mean post-intervention static and dynamic balance scores increased in the intervention group by 1.6 and 5.6 points, respectively, which indicates improvement in static and dynamic balance in this group. Furthermore, there was a significant decrease in proprioception error in the intervention group post-intervention (Tables 3 and 4).

Table 3.
Pre- and post-intervention outcome measure (Mean+SD) mean and standard deviation for control and experimental groups

Time		Pre-intervention	Post-intervention
Group	Variable	Mean+SD	Mean+SD
Control group	Pain intensity	3.93±1.75	5.13±1.29
	Level of disability	13.87±9.15	17.20±11.92
	Static balance	8.40±6.31	6.93±4.54
	Dynamic balance	93.85±5.16	92.94±7.79
	Proprioception	2.22±0.64	2.54±0.47
Experimental group	Pain intensity	5.73±1.63	3.67±1.96
	Level of disability	16.80±8.34	9.87±8.68
	Static balance	6.06±2.62	7.73±3.42
	Dynamic balance	92.15±10.63	97.84±10.56
	Proprioception	2.34±0.68	1.92±0.58

Table 4.
Two-way ANOVA test of the post-intervention outcome measure scores in the experimental versus control groups

Variable	Time	Group	time * group	Effect Size
Pain intensity	.320	.701	.001*	.203
Level of disability	.472	.380	.044*	.71
Static balance	.931	.507	.017*	.32
Dynamic balance	.299	.484	.015*	.36
Proprioception	.740	.110	.021*	.92
* = significant difference (p<0.05).				

Discussion

The aim of the present study was to investigate the effect of neuromuscular exercises on the intensity of pain, functional disability, balance, and proprioception of male military personnel with chronic LBP. In this regard, the results indicate that eight weeks of neuromuscular exercises could result in diminished pain severity in the intervention group. In other words, neuromuscular exercises might lead to a significant reduction in the severity of pain among the military personnel with chronic LBP.

Notably, the results of this study are in agreement with Suni *et al*.'s[38] findings who examined the effect of neuromuscular exercises and counseling on decreasing the absence of young soldiers with LBP. They found exercise and education had preventive effects on improving the LBP region control in military environments. They also tested the effectiveness of neuromuscular exercises and counseling on back pain among the healthcare personnel with nonspecific chronic LBP and observed exercising one time per week for six months along with five sessions of counseling on back care after work in a real life environment reduced the severity of LBP pain as well as the fear of pain due to the interventions; however, their intervention model was not economical. Suni et al. also explored the effect of neuromuscular exercises and counseling on back pain among the female nurse personnel with nonspecific chronic LBP in which their intervention resulted in improved ability to work and quality of life.[40] It appeared the exercises used by Suni et al. were effective at mitigating pain and pain-associated improvement.[39]

The results of the present study also show eight weeks of neuromuscular exercises had a significant effect on the level of disability in the intervention group compared to the control group. Accordingly, this may indicate that neuromuscular exercises led to the increased functional ability of military personnel with chronic LBP. Similarly, Taulaniemi *et al*. investigated the effect of neuromuscular exercises on reducing the severity of LBP as well as improving the physical functioning in nursing tasks among female healthcare staff.[41] They found neuromuscular exercises were effective at reducing pain and improving back movement control, abdominal power, and physical performance of nursing tasks.[41] Bauer *et al*.[21] investigated the effectiveness of doing neuromuscular exercises for six months on back motion. They found neuromuscular exercises improved back movement in the short term, which might have also demonstrated neuromuscular functioning integrity. In addition, they revealed that designing an optimal neuromuscular exercise program that would achieve long-term improvement in movement variability would require further research.

Garcia et al. examined 148 patients with nonspecific chronic LBP and then compared the effects of the McKenzie method and a back health educational program.[43] They found both interventions led to a diminished level of disability in these patients. Nevertheless, they reported exercise therapy using the McKenzie method was more effective as compared to the back health educational program. In this regard, Shamsi *et al*.[44] compared the effects of central stability exercises and traditional trunk exercises on patients with chronic LBP using pelvic lumbar stability functioning tests. Statistical analysis of the results showed significant progress in stability test scores as well as a reduction of disability and pain in the central stability of the exercise group.

Some studies have shown increased pain causes an increase in the range of variations as well as the impaired balance in the patients with LBP.[45,46] In such patients, the delay in the contraction of trunk muscles, and especially deep muscles, as well as the altered adaptation between the trunk muscles status during pain causes impaired stability and balance. Accordingly, rehabilitation programs are essential to improve the balance of these individuals. Carpes *et al*.[46] and Rhee *et al*.[47] dealt with examining the effect of dry-land stability exercises on the balance of the patients with LBP. As a result, both studies concluded these exercises lead to the increased balance and stability in these patients. The duration of exercises and the type of exercises in these studies were different from the present study. In Carpes *et al*.'s[46] study, 20 subjects underwent dry-land strength exercises for 20 sessions, which resulted in improved balance in these patients. Rhee *et al*.[47] also had 20 subjects undergo dryland core stability training programs five times per week for four weeks. In that study, subjects' balance was assessed using the center of pressure displacement index and showed significant improvement.

Neuromuscular exercises can improve the ability of the nervous system to generate a fast and desired muscle stimulus pattern that enhance dynamic joint stability, reduce forces exerted to the joint, and improve movement patterns.[48] Maintaining balance depends on a person's sensory information and is affected by coordination, joint range of motion, and strength.[49] In this regard, planned and proper neuromuscular exercises are important in improving the neuromuscular coordination based on a wide range of strengths, ranges of motion, and proprioception function.[50]

Moreover, Waldén *et al*.[51] and Banderchet *et al*.[52] dealt with the effect of neuromuscular exercises on knee proprioception. Recent research has suggested an index like proprioception is associated with LBP, and LBP patients have a weaker proprioception compared to healthy individuals.[53] Several studies have also shown proprioception is trainable, and rehabilitation programs that mostly train proprioception can improve functional movements.[49-52] Accordingly, balance exercises, which are known as a subset of neuromuscular exercises, have been proposed to improve the proprioception disorders.[54] Neuromuscular exercises are typically practiced in the weight-bearing functional situations, which emphasize quality of movement in the truck and lower limbs. Another possible mechanism of these changes can be found in the effectiveness of neuromuscular exercises on the proprioception receptors. The information obtained from these receptors can help in the precise and delicate implementation of movements as well as in the provision of active stability thereby supporting balance.[55] For rehabilitation of the movement patterns and prevention of the long-term motor disorders, an overload pattern of neuromuscular exercises is used for physiological stimulation of sensory feedback changes, and thus, for improving the proprioception and neuromuscular control mechanisms.[56] The primary emphasis of neuromuscular exercises is not on changing strength; rather, it focuses on improving dynamic balance and proprioception receptors, which are defined as the awareness of the posture, movement, and changes in the balance as well as understanding the position, weight, and resistance of objects in regards to the body. The focus of this type of exercise is on the proper posture and position of the body for improved dynamic muscular balance during functional activities.[57] Therefore, improved muscular balance can control abnormal transfer of the joint during these activities. Neuromuscular exercises also tend to improve posture control and implementation of functions by challenging limbs in functional positions.[58] Consequently, the exercises used in the present study focused on improving the strength, stamina, balance, posture control, and enhanced range of pelvic lumbar muscular motion, which also stabilize the core's muscles.

Limitations

The limitations in this study include a low sample size, spatial constraints, the lack of female subjects, and the lack of long-term follow up testing. Furthermore, according to the Iranian laws governing military environments, it was impossible to have female researchers measure female subjects. Lack of access to advanced laboratory equipment, time constraints and lack of financial support were the other limitations of this study. Iranian cultural constraints and the unavailability of military personnel due to their jobs and insufficient support could have also affected this study's results negatively.

Conclusion

The results of the present study indicate performing neuromuscular exercises for eight weeks led to diminished severity of pain, increased functional ability, as well as improved static and dynamic balance and ameliorated proprioception among male military personnel with LBP. Preventive measures in military personnel should focus on mitigating back injury; therefore, the heavy burden of musculoskeletal diseases among the military personnel could be diminished. As such, the results of this study suggest that performing neuromuscular exercises can be effective in mitigating LBP. Considering the positive and considerable effect of the neuromuscular exercises performed in this study, the low-cost of the implementation of the exercises into existing programs and their simplicity, these exercises can be considered ideal for military personnel.

Acknowledgments

The authors would like to thank all the subjects and the authorities of Baqiyatallah University of Medical Sciences who kindly cooperated in this research.

References

1. Andersson GB. Epidemiological features of chronic low-back pain. Lancet. 1999;354(9178): 581-585.
2. Weissenfels A, Teschler M, Willert S, Hettchen M, Fröhlich M, Kleinöder H, et al. Effects of whole-body electromyostimulation on chronic nonspecific low back pain in adults: a randomized controlled study. J Pain Res. 2018;11: 1949.

3. Azevedo BR, Oliveira CB, Araujo GMD, Silva FG, Damato TM, Pinto RZ, Christofaro DG. Is there equivalence between the electronic and paper version of the questionnaires for assessment of patients with chronic low back pain? Spine. 2020;45(6): E329-E335.
4. Hartvigsen J, Hancock MJ, Kongsted A, Louw Q, et al. What low back pain is and why we need to pay attention. Lancet. 2018;391(10137): 2356-2367.
5. O'Sullivan K, O'Sullivan PB, O'Keeffe M. The Lancet series on low back pain: reflections and clinical implications. 2019;53(7):392-393.
6. Palazzo C, Ravaud J-F, Papelard A, Ravaud P, Poiraudeau S. The burden of musculoskeletal conditions. PloS One. 2014;9(3): e90633.
7. Manchikanti L, Singh V, Datta S, Cohen SP, Hirsch JA, American Society of Interventional Pain Physicians. Comprehensive review of epidemiology, scope, and impact of spinal pain. Pain Phys. 2009; 12(4): E35-E70.
8. Suh JH, Kim H, Jung GP, Ko JY, Ryu JS. The effect of lumbar stabilization and walking exercises on chronic low back pain: a randomized controlled trial. Medicine. 2019; 98(26): e16173.
9. Berenshteyn Y, Gibson K, Hackett GC, Trem AB, Wilhelm M. Is standing balance altered in individuals with chronic low back pain? A systematic review. Disabil Rehabil. 2019;41(13): 1514-1523.
10. Frank C, Page P, Lardner R. Assessment and treatment of muscle imbalance: the Janda approach. Champaign, IL: Human Kinetics, 2009.
11. Rhon DI, Teyhen DS, Shaffer SW, Goffar SL, Kiesel K, Plisky PP. Developing predictive models for return to work using the Military Power, Performance and Prevention (MP3) musculoskeletal injury risk algorithm: a study protocol for an injury risk assessment programme. Inj Prev. 2018;24(1): 81-88.
12. Vining R, Minkalis A, Long CR, Corber L, Franklin C, Gudavalli MR, et al. Assessment of chiropractic care on strength, balance, and endurance in active-duty US military personnel with low back pain: a protocol for a randomized controlled trial. Trials. 2018;19(1): 671.
13. Koes BW, Van Tulder M, Lin CWC, Macedo LG, McAuley J, Maher C. An updated overview of clinical guidelines for the management of non-specific low back pain in primary care. Eur Spine J. 2010;19(12): 2075-2094.
14. Swinkels IC, van den Ende CH, van den Bosch W, Dekker J, Wimmers RH. Physiotherapy management of low back pain: does practice match the Dutch guidelines? Aust J Physiother. 2005;51(1): 35-41.
15. Yang Q, Wang Z, Yang L, Xu Y, Chen LM. Cortical thickness and functional connectivity abnormality in chronic headache and low back pain patients. Hum Brain Mapp. 2017;38(4): 1815-1832.
16. Lehtola V, Luomajoki H, Leinonen V, Gibbons S, Airaksinen O. Efficacy of movement control exercises versus general exercises on recurrent sub-acute nonspecific low back pain in a sub-group of patients with movement control dysfunction. Protocol of a randomized controlled trial. BMC Musculoskelet Disord. 2012;13(1): 55.
17. Rowley KM, Engel T, Kulig K. Trunk and hip muscle activity during the Balance-Dexterity task in persons with and without recurrent low back pain. J Electromyogr Kines. 2020;50: 102378.
18. Smidt N, de Vet HC, Bouter LM, Dekker J. Effectiveness of exercise therapy: a best-evidence summary of systematic reviews. Aust J Physiother. 2005;51(2): 71-85.
19. Mascarin NC, Vancini RL, dos Santos Andrade M, de Paiva Magalhães E, de Lira CAB, Coimbra IB. Effects of kinesiotherapy, ultrasound and electrotherapy in management of bilateral knee osteoarthritis: prospective clinical trial. BMC Musculoskel Dis. 2012;13(1): 182.
20. Tsai L-C, Sigward SM, Pollard CD, Fletcher MJ, Powers CM. Effects of fatigue and recovery on knee mechanics during side-step cutting. Med Sci Sports Exerc. 2009;41(10): 1952-1957.
21. Bauer C, Kankaanpää M, Meichtry A, Rissanen S, Suni J. Efficacy of six months neuromuscular exercise on lumbar movement variability – a randomized controlled trial. J Electromyogr Kines. 2019;48: 84-93.
22. Suni JH, Rinne M, Kankaanpää M, Taulaniemi A, Lusa S, et al. Neuromuscular exercise and back counselling for female nursing personnel with recurrent non-specific low back pain: study protocol of a randomised controlled trial (NURSE-RCT). BMJ Open Sport Exerc Med. 2016;2(1): e000098.
23. Balagué F, Mannion AF, Pellisé F, Cedraschi C. Non-specific low back pain. Lancet. 2012;379(9814): 482-491.
24. Motallebi L, Mohseni Bandpei MA, Rahmani N. Effects of stabilization exercises on pain intensity, functional disability and cross sectional area of multifidus muscle in women with non-specific chronic low back pain. J Mazandaran Uni Med Sci. 2013;23(100): 11-19.
25. Akodu AK, Akindutire OM. The effect of stabilization exercise on pain-related disability, sleep disturbance, and psychological status of patients with non-specific chronic low back pain. Kor J Pain. 2018;31(3): 199.
26. Hemmati S, Rajabi R, Karimi N, Jahandideh AA. Effects of consecutive supervised core stability training on pain and disability in women with nonspecific chronic low back pain. Koomesh. 2011;12(3): 244-252.
27. Knop C, Oeser M, Bastian L, Lange U, Zdichavsky M, Blauth M. Development and validation of the visual analogue scale (VAS) spine score. Der Unfallchirurg. 2001;104(6): 488-497.
28. Fairbank JC, Pynsent PB. The Oswestry disability index. Spine. 2000; 25(22):2940-2953.
29. Mousavi SJ, Parnianpour M, Mehdian H, Montazeri A, Mobini B. The Oswestry disability index, the Roland-

Morris disability questionnaire, and the Quebec back pain disability scale: translation and validation studies of the Iranian versions. Spine. 2006;31(14): E454-E9.
30. Gribble PA, Hertel J, Plisky P. Using the Star Excursion Balance Test to assess dynamic postural-control deficits and outcomes in lower extremity injury: a literature and systematic review. J Athl Train. 2012;47(3): 339-357.
31. Shaffer SW, Teyhen DS, Lorenson CL, Warren RL, Koreerat CM, Straseske CA, et al. Y-balance test: a reliability study involving multiple raters. Mil Med. 2013;178(11): 1264-1270.
32. Cote KP, Brunet ME, II BMG, Shultz SJ. Effects of pronated and supinated foot postures on static and dynamic postural stability. J Athl Train. 2005;40(1): 41.
33. Şenol, D, Altinoğlu M, Toy S, Kisaoğlu A, Özbağ D. Investigation of the relationship of Q Angle and stork balance stand test with somatotype in healthy young individuals. Med Records. 2019;1(3): 60-66.
34. McCurdy K, Langford G. The relationship between maximum unilateral squat strength and balance in young adult men and women. J Sport Sci Med. 2006;5(2): 282.
35. Nelson JK, Johnson BL. Effects of local and general fatigue on static balance. Percept Mot Skills. 1973;37(2): 615-618.
36. Newcomer KL, Laskowski ER, Yu B, Johnson JC, An K-N. Differences in repositioning error among patients with low back pain compared with control subjects. Spine. 2000;25(19): 2488-2493.
37. Letafatkar A, Nazarzadeh M, Hadadnezhad M, Farivar N. The efficacy of a HUBER exercise system mediated sensorimotor training protocol on proprioceptive system, lumbar movement control and quality of life in patients with chronic non-specific low back pain. J Back Musculoskelet. 2017;30(4): 767-778.
38. Suni JH, Taanila H, Mattila VM, Ohrankämmen O, Vuorinen P, et al. Neuromuscular exercise and counseling decrease absenteeism due to low back pain in young conscripts: a randomized, population-based primary prevention study. Spine. 2013;38(5): 375-384.
39. Suni JH, Rinne M, Kankaanpää M, Taulaniemi A, Lusa S, et al. Neuromuscular exercise and back counselling for female nursing personnel with recurrent non-specific low back pain: study protocol of a randomised controlled trial (NURSE-RCT). BMJ Open Sport Exerc Med. 2016;2(1): e000098.
40. Suni JH, Kolu P, Tokola K, Raitanen J, Rinne M, et al. Effectiveness and cost-effectiveness of neuromuscular exercise and back care counseling in female healthcare workers with recurrent non-specific low back pain: a blinded four-arm randomized controlled trial. BMC Publ Health. 2018;18(1): 1376.
41. Taulaniemi A, Kankaanpää M, Tokola K, Parker J, Suni JH. Neuromuscular exercise reduces low back pain intensity and improves physical functioning in nursing duties among female healthcare workers; secondary analysis of a randomised controlled trial. BMC Musculoskelet Disord. 2019;20(1): 328.
42. Wright, A., Hannon, J., Hegedus, E. J., Kavchak, A. E. Clinimetrics corner: a closer look at the minimal clinically important difference (MCID). J Man Manip Ther. 2012;20 (3):160-166.
43. Garcia AN, Costa LdCM, da Silva TM, Gondo FLB, Cyrillo FN, et al. Effectiveness of back school versus McKenzie exercises in patients with chronic nonspecific low back pain: a randomized controlled trial. Phys Ther. 2013;93(6): 729-747.
44. Shamsi MB, Sarrafzadeh J, Jamshidi A. Comparing core stability and traditional trunk exercise on chronic low back pain patients using three functional lumbopelvic stability tests. Physiother Theor Pract. 2015;31(2): 89-98.
45. Field TM. Massage therapy effects. Am Psychol. 1998;53(12): 1270.
46. Carpes FP, Reinehr FB, Mota CB. Effects of a program for trunk strength and stability on pain, low back and pelvis kinematics, and body balance: a pilot study. J Bodyw Mov Ther. 2008;12(1): 22-30.
47. Rhee HS, Kim YH, Sung PS. A randomized controlled trial to determine the effect of spinal stabilization exercise intervention based on pain level and standing balance differences in patients with low back pain. Med Sci Mon Int Med J Exp Clin Res. 2012;18(3): CR174.
48. Sokhangu MK, Rahnama N, Etemadifar M, Rafeii M. The effect of neuromuscular exercise on balance and motor function in woman with multiple sclerosis. J Urmia Uni Med Sci. 2018;29(5): 362-371.
49. Bressel E, Yonker JC, Kras J, Heath EM. Comparison of static and dynamic balance in female collegiate soccer, basketball, and gymnastics athletes. J Athl Train. 2007;42(1): 42.
50. Myer GD, Ford KR, Palumbo OP, Hewett TE. Neuromuscular training improves performance and lower-extremity biomechanics in female athletes. J Strength Cond Res. 2005;19(1): 51-60.
51. Waldén M, Atroshi I, Magnusson H, Wagner P, Hägglund M. Prevention of acute knee injuries in adolescent female football players: cluster randomised controlled trial. BMJ. 2012;344: e3042.
52. Barendrecht M, Lezeman HC, Duysens J, Smits-Engelsman BC. Neuromuscular training improves knee kinematics, in particular in valgus aligned adolescent team handball players of both sexes. J Strength Cond Res. 2011;25(3): 575-584.
53. Brumagne S, Cordo P, Verschueren S. Proprioceptive weighting changes in persons with low back pain and elderly persons during upright standing. Neurosci Lett. 2004;366(1): 63-66.
54. Ageberg E, Link A, Roos EM. Feasibility of neuromuscular training in patients with severe hip or knee

OA: the individualized goal-based NEMEX-TJR training program. BMC Musculoskel Dis. 2010;11(1): 126.
55. Lephart SM. Proprioception and neuromuscular control in joint stability. Champaign, IL: Human Kinetics, 2000: 405-413.
56. Zech A, Huebscher M, Vogt L, Banzer W, Haensel F, Pfeifer K. Neuromuscular training for rehabilitation of sports injuries: a systematic review. Med Sci Sports Exerc. 2009;41(10): 1831-1841.
57. Hoang P, Schoene D, Gandevia S, Smith S, Lord SR. Effects of a home-based step training programme on balance, stepping, cognition and functional performance in people with multiple sclerosis – a randomized controlled trial. Mult Scler J. 2016;22(1): 94-103.
58. Ageberg E, Roos EM. Neuromuscular exercise as treatment of degenerative knee disease. Exerc Sport Sci Rev. 2015;43(1): 14-22.